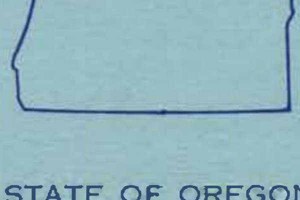
BULLETIN 79

ENVIRONMENTAL GEOLOGY OF INLAND TILLAMOOK AND CLATSOP COUNTIES OREGON



STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

1973

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ENVIRONMENTAL GEOLOGY OF INLAND TILLAMOOK AND CLATSOP COUNTIES, OREGON

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July 1973

FOREWORD

In 1972 the Department of Geology and Mineral Industries published a report on the environmental geology of the coastal region of Tillamook and Clatsop Counties. The primary purpose of that report was to provide basic geologic information about the coastal zone and to outline areas of geologic hazards. County officials and planners need this type of information in order to establish suitable zoning regulations and land-use planning. Developers, engineers, and private citizens utilize the report to determine potential problems before and not after an engineering project or development is undertaken. Large financial losses and possible injury can thereby be avoided.

This bulletin, covering the inland territory to the east, has been prepared at the request of Tillamook and Clatsop Counties to compliment the coastal study. The rugged topography in the eastern parts of these counties produces problems of land stability that cannot be ignored. Proper guidance is needed for the increasing numbers of areas being opened up to summer homesites or other recreational uses. Geologic processes and their related hazards must be considered during the decision-making process so that the local governmental agencies can carry out intelligent planning for the future. It is the purpose of this study to provide that kind of information.

R. E. Corcoran
Oregon State Geologist

July 1973

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INTRODUCTION

Purpose

As development continues to encroach upon open land, private citizens, engineers, developers, planners, and county officials are experiencing an increasing need for information about geologic hazards. More and better information is needed regarding the landslide and flood potentials of much of Oregon. It is the purpose of this study to evaluate these and related hazards in inland Tillamook and Clatsop Counties.

A knowledge of geologic hazards is an aid to the planner and an asset to the responsible developer. It promotes safe decisions which pay long-range dividends. Through the proper use of such knowledge, damages and liabilities can be minimized. Moreover, maintenance costs can be reduced, especially in the construction of highways and roads.

In analyzing the hazards of the inland area, the aim of this study is to provide data of a general nature to be used in future planning and development. It is the task of the planner, however, to arrive at a final decision regarding the wisest use of the land. In some areas the presence of a particularly critical hazard may override all other considerations. In many areas the weight of nongeologic input may justify development if corrective measures are taken. The planner must consider input from a number of sources in addition to geology; rarely do geologic conditions directly dictate policy.

Geologic processes will continue to have a major effect on the uplands in the future. Human activities in this region must be considered in the light of these processes and their related hazards so that intelligent planning can incorporate an understanding of them into the decision-making process. Efficient land use and safety in inland Tillamook and Clatsop Counties can be served by the use of information presented in this report.

Previous Work

The study area is relatively far removed from population centers and is lacking in significant mineral wealth; it has been the focus of very little geologic investigation. Warren and others (1945) and Wells and Peck (1961) provided reconnaissance map coverage of the area in regional studies of much larger scope. Topical studies of the geology of Saddle Mountain and related volcanic rocks were conducted by Layfield (1936a,b) and Baldwin (1952). Baldwin and Roberts (1952) included part of the Nestucca River drainage in their map of the Spirit Mountain (Grand Ronde) quadrangle. Dodds (1963) mapped the western half of the Svensen quadrangle.

Flood data along the major streams is recorded by Hulsing and Kallio (1964) and Waananen and others (1971), and site investigations for several possible damsites along the Nehalem River are provided by Young and Colbert (1965). This study is an inland continuation of the coastal investigation of Tillamook and Clatsop Counties by Schlicker and others (1972).

Sources of Data

The geologic and hazards maps are based upon field investigations, aerial photographic investigations, previous published and unpublished reports, and numerous discussions with others having geologic experience in the area. Quarry data were provided by the Oregon State Highway Division, and ground-water data were provided by the Portland office of the Water Resources Division of the U. S. Geological Survey.

Implementation of This Study

In using this bulletin the planner should first consult the geologic hazards maps and the geologic maps (in pocket) to identify potential hazards. A list of recommendations is given in the summary to assist him. He should then consult the supporting text to evaluate the hazards in more detail.

If it is determined that hazards may exist at the site of a proposed development, the developer should be required to demonstrate a solution to the problem. In most areas this should involve an on-site reassessment of the geologic conditions on a scale larger than that of this reconnaissance investigation. If critical problems do exist, the planners should require that the developer obtain the services of a competent engineering geologist to perform a more rigorous on-site investigation. The engineering geologist should assess the feasibility of the project and outline the corrective measures needed to insure that the health, safety, and welfare of the public are not threatened.

In many areas the potential effect of a geologic hazard is dependent upon the nature of the proposed development and not solely on the geologic conditions. For instance, the constraints posed by a large supermarket are considerably more restrictive than those posed by a single trailer home. Likewise a single dwelling in an isolated area of mass movement topography may be stable, whereas high density development would pose serious problems.

In future years various aspects of this study will no doubt be incorporated into revised and refined zoning regulations, building codes, and other documents. Policy statements and standards will directly and indirectly incorporate much of the information that is presented here. The standards needed for the orderly implementation of the general conclusions presented in this report will require additional investigation in many instances and much thought and discussion on the part of the planners.

For the present the planner will wish to use this study in the most comprehensive and realistic way possible. Following the procedure outlined above, this study can be used to oversee and regulate large projects, such as subdivisions, and projects in areas of critical hazards. The planner may also wish to refer to this study in advising parties involved in smaller, less demanding developments in areas of less critical hazards.

Acknowledgments

The author greatly appreciates the cooperation and help given by many individuals and organizations in the preparation of this report. Special acknowledgment is made to Jack D. Lesch, Tillamook County Planner, and the members of the Clatsop-Tillamook Council of Governments, who were instrumental in initiating this study. The assistance of Robert Logan, Director, and Ray Hinds and Cary Vlahovich of the State Division of Local Government Relations is also appreciated.

Robert J. Deacon of Shannon & Wilson assisted in field reconnaissance investigations in the early stages of this study. Dennis Rittenback of the Clatsop-Tillamook Council of Governments provided much of the data presented in the geographic section of this report, and F. J. Frank of the U. S. Geological Survey provided the well data upon which much of the ground-water section is based. The photography and preparation of prints for this publication were by Greg Paul, student at Portland State University.

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GEOGRAPHY

Location and Extent

The study area is made up of the Columbia River Valley in northeastern Clatsop County and the drainage basins of the Nehalem, Wilson, Trask, and Nestucca Rivers in inland Tillamook and Clatsop Counties, Oregon (Figure 1). Some of the upland areas separating the major streams are not included in the investigation. Total extent of the study area is approximately 820 square miles.

The study area lies within the Svensen, Cathlamet, Saddle Mountain, Birkenfeld, Enright, Timber, Blaine, and Grand Ronde 15' quadrangles. Access is provided by U. S. Highway 30 along the Columbia River, State Highway 202 and a county road along the Nehalem River, State Highway 6 along the Wilson River, the Trask Highway and Trask Summit Road along the Trask River, and a county road along the Nestucca River. U. S. Highway 26 (Sunset Highway) passes diagonally through the region, and numerous secondary paved and unpaved roads provide restricted access to the more remote areas.

Climate and Vegetation

Owing largely to the influence of the ocean the climate of the uplands is moist, marine, and temperate. Summers are generally cool and winters are mild. The average annual precipitation exceeds 80 inches throughout most of the region, exceeds 120 inches in parts of the Trask River drainage, and approaches 150 inches in the upper reaches of the Wilson River. Precipitation occurring in the winter months (October through March) amounts to 75 to 85 percent of total annual precipitation. Snowfall is moderate in the interior, averaging 4 feet per year at Lees Camp along the Wilson River.

Fog and cloudy weather are the rule during the winter months. Moderate rains are common and may last for days. Severe rainstorms, when they occur, often result in flooding of the lowlands and flash flooding of side channels in the uplands. Relative humidity is generally high.

The maximum temperature recorded in the Tillamook uplands was 106° F in the bottom of the Wilson River canyon at Lees Camp (Rittenback, written communication, 1972). A minimum of 8° F has been recorded a short distance from the study area at Vernonia. Average minimum temperature ranges from 35° F in January to 48° F in August. Average maximum temperature ranges from 49° in January to 69° in August. The growing season at Lees Camp is 140 days.

Forest growth in the uplands is generally young owing to the extensive damage of the Tillamook burns in the 1930's. Many slopes remain only sparsely forested. Elsewhere conifer trees dominate the vegetation. The most common native trees are Douglas fir (Pseudotsuga mensiesii), Grand fir (Abies grandis), Western hemlock (Tsuga heterophylla), Western red cedar (Thuja plicata). Red alder (Alnus rubra) dominates the creek bottoms. Other minor species found in the uplands include Large-leafed maple (Acer Macrophyllum), Vine maple (Acer circinatum), Pacific dogwood (Cornus nuttallii), Pacific blue elderberry (Sambucus caerulea), and Western blueberry (Vaccinium uliginosum).

Population Trends and Land Use

Figures released by the U. S. Department of Census indicate that the population of Tillamook County declined from 18,995 in 1960 to 17,930 in 1970 (—5.4 percent). The population of Clatsop County increased from 27,380 to 28,473 (+4 percent) during the same period. The population of upland Tillamook County is very small and that of upland Clatsop County is declining. The Knappa-Brownsmead and Svensen areas of northern Clatsop County increased 25 percent and 21 percent respectively between 1960 and 1970.

Land use trends reflect the loss in population. The fisheries industry is at low ebb and logging and lumbering industries are declining after peaking in 1952. Dairying and farming, which employ relatively few people on a full-time basis, are holding steady. The mineral industry is negligible.

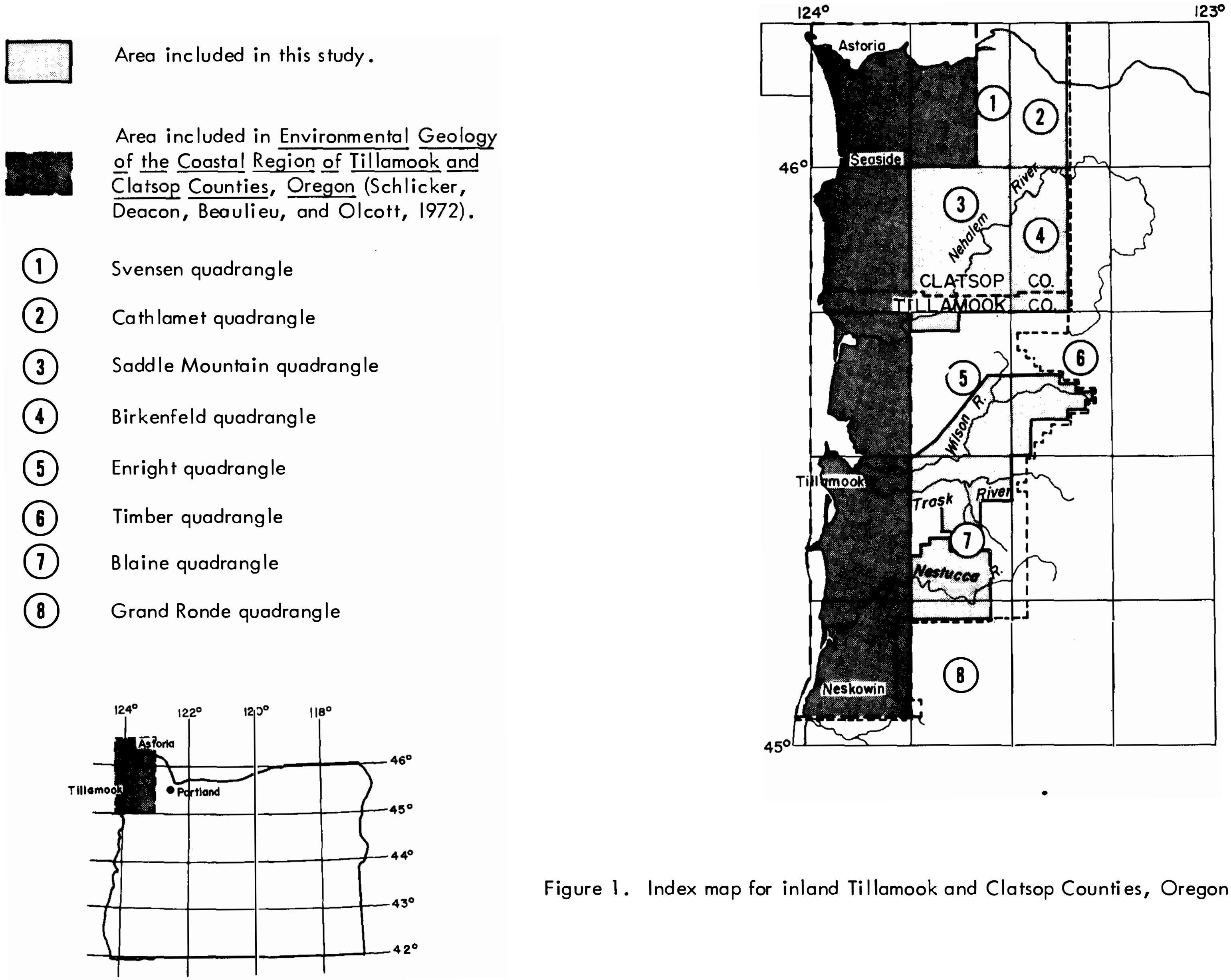


Figure 1. Index map for inland Tillamook and Clatsop Counties, Oregon.

In the years ahead the esthetic appeal of the uplands will become increasingly evident to the surrounding more populated areas. Various forms of recreation and tourism including fishing, swimming, hiking, sight-seeing, and big game hunting will exert a growing impact on the uplands area. Already, overnight and day-use facilities are located along the Nehalem, Wilson, Trask, and Nestucca Rivers. In addition, large corridors along the Nehalem and Trask Rivers have Tillamook County deed restrictions for County park and recreation purposes.

As the need for improved access develops, the need for road construction and maintenance will continue to grow. In the valley bottoms, homes, summer cottages, and travel-oriented facilities will continue to appear. In order to maximize the benefits and minimize the dangers inherent in these and other developments, a coherent regional land-use plan which includes a consideration of geologic hazards is required.

Topography

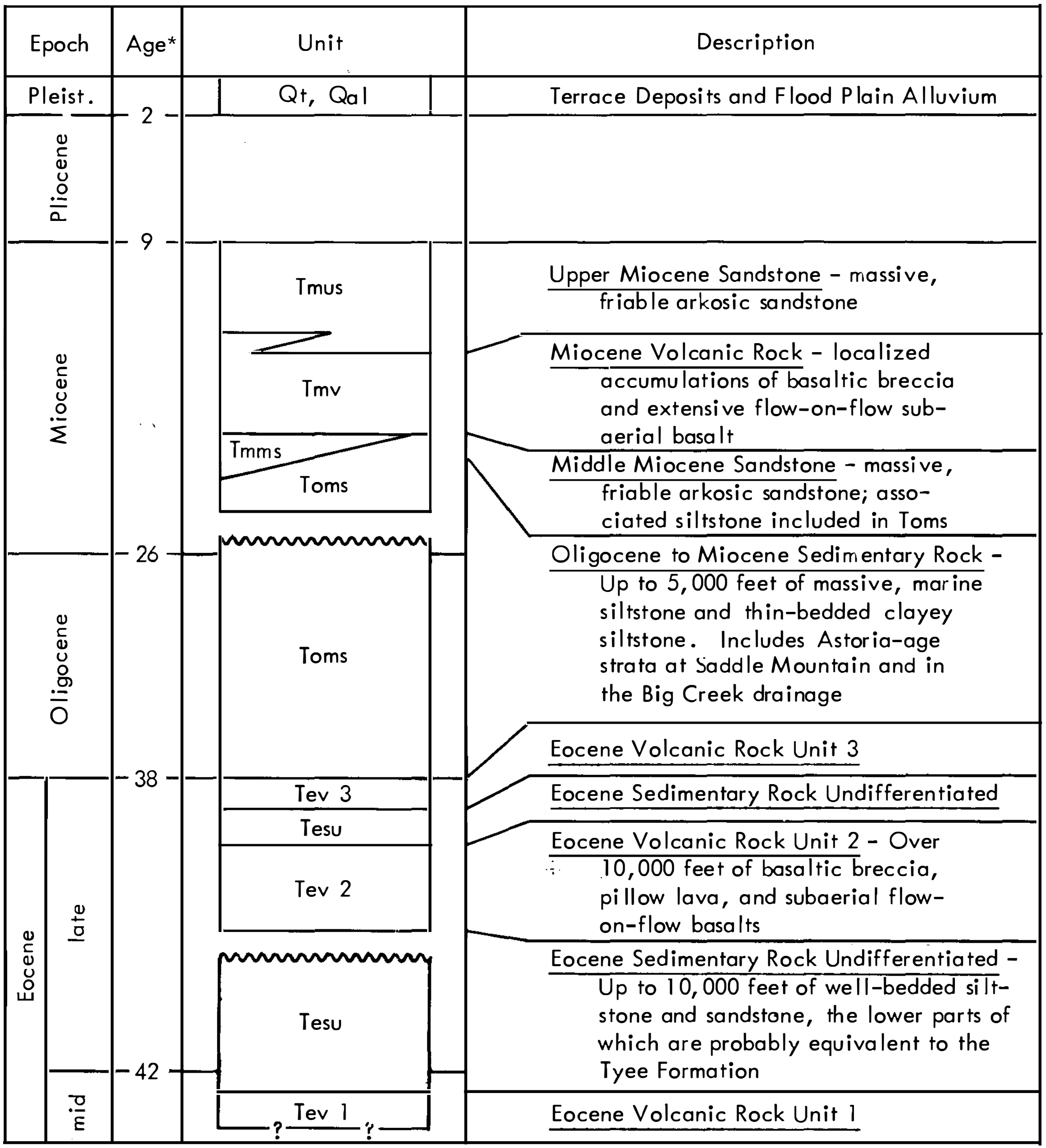
The study area is underlain by mountains, gentle slopes and hills along the Columbia River, deeply incised canyons along the Wilson and Trask Rivers, rolling topography along the Nehalem River, and moderately hilly country along the Nestucca River. In the northern Svensen quadrangle gently dipping volcanic rock underlying Nicolai Mountain (3,020 feet) forms a gentle slope towards the Columbia River to the north. Wickiup Mountain (2,702 feet) to the west is separated from Nicolai Mountain by the deep canyon of Big Creek, the major drainage in the area.

Typical peak elevations in the Nehalem River Basin are about 1,800 feet in the lower reaches, 1,300 feet in the middle and upper reaches in the Saddle Mountain quadrangle, and 2,800 feet in the southern Birkenfeld quadrangle. Relief is generally 1,000 feet or less except at Saddle Mountain (elev. 3,283 feet) and Humbug Mountain (elev. approximately 2,500 feet), which rise 2,000 feet and 1,300 feet respectively above the surrounding ridge crests. Major streams include the Salmonberry River, Fishhawk Creek, Little Fishhawk Creek, the Little North Fork of the Nehalem River, Wheeler Creek, and Buster Creek.

The Wilson River drainage basin is characterized by steep rocky canyons and sharp crestlines, which rise to elevations of 3,226 feet at Kings Mountain and 3,409 feet at Hembre Ridge. Relief is approximately 2,000 to 2,500 feet. Major streams include Elk and Drift Creeks in the upper reaches of the Wilson River and Jordan and Fox Creeks in the middle reaches.

The highest peaks in the drainage basin of the Trask River are Gold Peak (2,847 feet) and Edwards Butte (3,168 feet). Maximum relief is approximately 2,500 feet in the north-central parts of the Blaine quadrangle. Farther south along the South Fork of the Trask River, peak elevations are lower and creek elevations are higher so that relief is generally 1,500 feet or less in the central Blaine quadrangle. Major streams include the North, East, and South Forks of the Trask River, Edwards Creek, and Bark Shanty Creek.

Peaks in the Nestucca River drainage include Mount Hebo (3,174 feet), High Peak (2,800 feet), and Grindstone Mountain (3,012 feet). Elevations of the Nestucca River vary from 200 feet on the west to 800 feet on the east. Although maximum relief in the area is similar to that of the Wilson River, slope angles are more moderate and the overall terrain is more gentle. Major streams draining south into the Nestucca River include Moor, Bays, Clarence, and Slick Rock Creeks. Streams draining north include Alder, Limestone, and Niagara Creeks.



*millions of years

Figure 2. Stratigraphic and time chart for geologic units in the study area.

GEOLOGY

Geologic Units

Indurated rocks ranging in age from middle Eocene to upper Miocene underlie the project area (Figure 2). They include three Eocene volcanic rock units totalling 20,000 feet in thickness, one undifferentiated Eocene sedimentary rock unit (Tesu) at least 5,000 to 10,000 feet thick, up to 5,000 feet of undifferentiated Oligocene to Miocene sedimentary rock (Toms), approximately 500 feet of sandstone of middle Miocene age (Tmms), up to 1,400 feet of middle Miocene volcanic rock (Tmv), and up to 1,000 feet of upper Miocene sandstone (Tmus). Tertiary intrusive rock (Ti/Tic) of Eocene and Miocene age cuts all the stratigraphic units except the upper Miocene sandstone. Mantling the consolidated rock units are terrace deposits (Qt) along the major streams and alluvium (Qal) along the Columbia River.

Eocene volcanic rock unit-1 (Tev-1)

The lowermost stratigraphic unit in the mapped area (Tev-1) is composed primarily of volcanic rocks and is exposed in the lower valley walls of the upper Nestucca drainage in the southern Blaine and northern Grand Ronde quadrangles. The rocks were treated as part of the Tillamook Volcanics by Warren and others (1945) and as part of a lower Eocene basalt unit (Telb) by Wells and Peck (1961).

Eocene volcanic rock unit-1 consists of up to 1,000 feet of volcanic rock and subordinate baked sedimentary rock. The base is not exposed. The volcanic rocks consist of thick massive flows of dense pillow basalt (Figure 3) up to 100 feet in thickness and massive basaltic flows of zeolite-cemented lapilli tuff and tuff breccia up to 30 feet thick (Figure 4). The baked sedimentary rocks include thin-bedded siltstones and sandstones. Radiolarians have been recovered from them locally. The unit as a whole is riddled with numerous dikes and sills of basaltic rock, and several quarries situated along the Nestucca River utilize this intrusive rock.

A middle Eocene age is inferred for the unit on the basis of its stratigraphic position beneath a thick late Eocene section and the presence of Ulatisian foraminifers (MacLeod, oral communication, 1972). The unit may be equivalent to the Siletz River Volcanics of Snavely and Baldwin (1948) to the south, or it may represent a presently unrecognized episode of middle Eocene volcanism. Schlicker and Deacon (1967) document the presence of a volcanic unit immediately beneath the Yamhill Formation in the western Tualatin Valley to the east.

Eocene sedimentary rock undifferentiated (Tesu)

All Eocene sedimentary rock in the mapped area which is not arbitrarily included in the Eocene volcanic rock units and which underlies the uppermost occurrence of the Eocene volcanic rock is included in this unit. It includes sedimentary rock at a variety of stratigraphic levels including the interval between Tev-1 and Tev-2 in the Nestucca drainage, the interval beneath Tev-2 in the Wilson and Trask River drainages, and the interval between Tev-2 and Tev-3 in the Birkenfeld and Saddle Mountain quadrangles. In view of the widespread distribution and moderate to gentle attitudes within the unit, a conservative estimate of its total thickness is between 5,000 and 10,000 feet.

From scattered observations throughout the mapped area it is concluded that the Eocene sedimentary rock unit grades from medium-bedded hard and soft siltstone and sandstone low in the section in the Wilson and Trask Rivers to faintly and thin-bedded siltstones and subordinate basaltic sandstones in the middle of the section and ultimately into arkosic sandstones and siltstones high in the section along the Sunset Highway.

Low in the section the interbedded sandstones and siltstones vary from a few inches to a few feet in thickness and exhibit a lateral persistence that is suggestive of a turbidite origin (Figures 5 and 6).

Figure 3. Pillow structures in basaltic flow rock (Tev-1) near Alder Glen Forest Camp (sec. 32, T. 4 S., R. 7 W.) in the middle reaches of the Nestucca River. Note the well-defined boundaries and radial jointing of the pillows.

Figure 4. Thick flow breccias (Tev-1) overlying less resistant baked sedimentary rock in the middle reaches of the Nestucca River (sec. 3, T. 4 S., R. 8 W.).

Figure 5. Exposure of Eocene sedimentary rock undifferentiated (Tesu) along middle reaches of the Trask River (sec. 25, T. 1 S., R. 8 W.). Presence of rhythmic sandstone interbeds and abundant micaceous and carbonaceous material are suggestive of Tyee equivalence.

Figure 6. Well-bedded sedimentary rock of the undifferentiated Eocene sedimentary rock unit (Tesu) in the Trask River (sec. 25, T. 1 S., R. 8 W.). Similar exposures with a consistent southward dip are exposed intermittently for a distance of 2 miles in the river bed.

The sandstone interbeds are lithic to arkosic and invariably micaceous. In places the rocks also are high in organic content. Overall they are quite similar to parts of the Tyee Formation exposed elsewhere in the northern Coast Range. This part of the undifferentiated Eocene sedimentary rock unit is particularly well exposed at "the bend" (secs. 1, 12, T. 1 S., R. 8 W., and sec. 7, T. 1 S., R. 7 W.) of the Wilson River (Figure 7) and in the vicinity of the Trask Guard Station along the Trask River.

Higher in the section the Eocene sedimentary rock unit passes into a sequence of orange-brown, gritty, tuffaceous, thin-bedded siltstone and basaltic sandstone (Figures 8 and 9) which locally displays spheroidal weathering. Thin interbeds of tuff stand out as resistant ribs in places. Near Cedar Butte immediately west of the mapped area basaltic wackes up to 60 feet thick and finer-grained sediments rich in fossil pine needles and leaves are reported (Nelson and Shearer, 1969). Shallow-water deposition in basins adjacent to volcanic islands is suggested.

Along the Sunset Highway to the north the stratigraphically highest levels of the undifferentiated Eocene sedimentary rock unit are exposed above Eocene volcanic rock unit-2. They consist of a complex series of tuffaceous, thin-bedded, gritty siltstones overlain by massive, medium- to fine-grained, micaceous, arkosic, friable sandstone. Intercalated with the sedimentary rocks are submarine accumulations of pillow palagonite breccia and basaltic flow rock and associated flanking deposits of basaltic conglomerate and thick-bedded, greenish-gray, medium- to very coarse-grained, gritty basaltic sandstone. A shallow-water environment of deposition is suggested. For equivalent strata to the east Van Atta (1971) interprets a littoral to sublittoral regime on the basis of fossil remains, plant debris, grain texture, and primary sedimentary structures.

The undifferentiated Eocene sedimentary rock unit is interpreted to range throughout the late Eocene. The Tyee-like sedimentary rock deep in the Wilson River Canyon is tentatively assigned a Ulatisian age on the basis of microfossils (N. S. MacLeod, oral communication 1972). Strata higher in the section beneath the Eocene volcanic rock unit-2 may range into the late part of the late Eocene. Megafossils associated with the exposures in the Birkenfeld quadrangle establish a latest Eocene age for the upper part of the undifferentiated Eocene sedimentary rock unit in that area.

Because the Eocene sedimentary rock unit is a composite unit incorporating rocks of many stratigraphic levels, its stratigraphic relationships with other units are variable. Strata in the Nestucca River drainage are believed to be conformable over Eocene volcanic rock unit-1. Strata high in the section along the Sunset Highway are believed to be conformable over Eocene volcanic rock unit-2 and conformable under Eocene volcanic rock unit-3. Much of the strata in the Wilson River and Trask River drainages may underlie the Eocene volcanic rock unit-2 with angular unconformity. Nelson and Shearer (1969) map such an unconformity in the Cedar Butte area, and regional mapping by Snavely and MacLeod (oral communication, 1972) elsewhere indicate the presence of a regional unconformity within the late Eocene. Along the Wilson River attitudes within Eocene volcanic rock unit-2 are commonly much gentler than measured attitudes in nearby exposures of underlying undifferentiated Eocene sedimentary rock (Tesu).

Eocene volcanic rock unit-2 (Tev-2)

Eocene volcanic rock unit-2 consists of 15,000 feet or more of volcanic rock and subordinate intercalated sedimentary rock which lie stratigraphically above undifferentiated Eocene sedimentary rock in the Wilson and Trask River drainages. Additional exposures are also present along the middle and lower reaches of the Nehalem River. The unit caps the core of the northern Coast Range and is the most extensive unit in the mapped area. Eocene volcanic rock unit-2 was included in the Tillamook Volcanic series by Warren and others (1945) and was treated as lower Eocene basalt (Telb) and as upper Eocene volcanic and sedimentary rock (Teuv) by Wells and Peck (1961).

Eocene volcanic rock unit-2 consists of submarine flow rock, basaltic lapilli tuff, and tuff breccia in the southern Saddle Mountain and northern Enright quadrangles, tuff breccias in the southern Enright and northern Blaine quadrangles, tuff breccia and sedimentary rock in the southern Blaine and northern Grand Ronde quadrangles, and subaerial flow-on-flow basalt in the Timber quadrangle and the unmapped middle portions of the Enright quadrangle. Specifically, exposures along the Nehalem River are typified by massive, porphyritic, locally amygdaloidal and locally pillowed flow basalt with interbeds of orange to gray, faintly bedded to thin-bedded siltstone high in the section.

Figure 7. Dike of porphyritic igneous rock cutting baked sedimentary rock (Tesu) low in the stratigraphic section at the bend of the Wilson River (sec. 7. T. 1 S., R. 7 W.). Large sills and coarse-grained instrusive bodies crop out nearby.

Figure 8. Thin-bedded siltstone of the undifferentiated Eocene sedimentary rock unit (Tesu) cropping out immediately downstream from Blaine (sec. 30, T. 4 S., R. 8 W.) along the Nestucco River. Interbeds of fine-grained basaltic sandstone are present.

Figure 9. Exposure of undifferentiated Eocene sedimentary rock (Tesu) near the contact with the overlying volcanic rock (Tev-2) along Keenig Creek Road in the Enright quadrangle (sec. 26, T. 1 N., R. 8 W.). Note the distinct thin bedding and the interbeds of tuff. Not apparent in the photo are interbedded flows of crumbly basalt.

Figure 10. Massive basaltic breccia of Eocene volcanic unit-2. In this exposure much of the matrix of low temperature minerals and zeolites has been washed away leaving the actual basaltic fragments standing in relief.

Figure 11. Exposure of flow basalt assigned to Eocene volcanic rock unit-2 and located along the crest of Hembre Ridge (sec. 11, T. 1 S., R. 7 W.). A horizontal contact separates an upper lighter colored flow from the lower darker flow. Pillow structures are present in places in the lower flow.

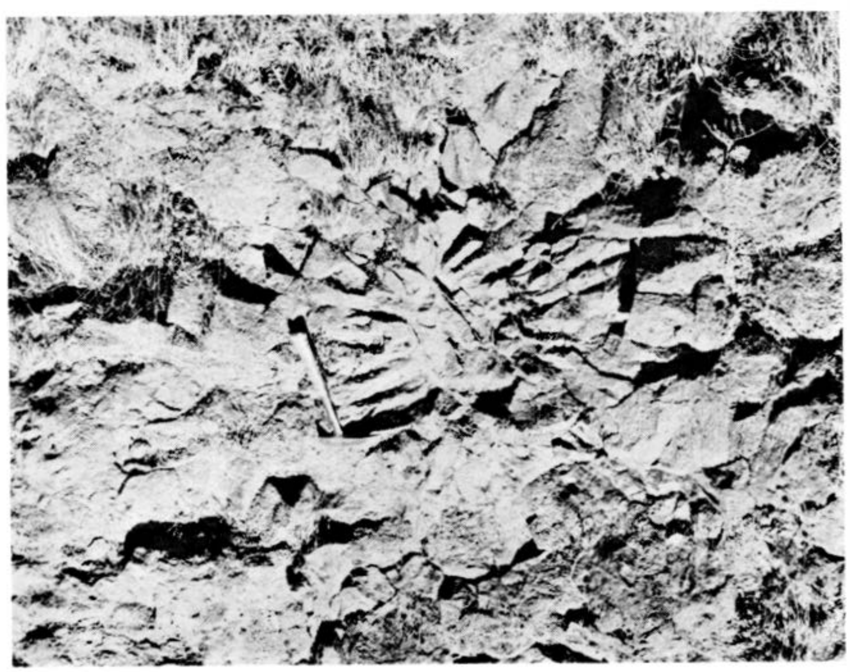


Figure 12. Pillow structure in dense Eocene volcanic flow rock. Pillow structures are indicative of flowage under water and are present in Eocene volcanic unit-1 and parts of Eocene volcanic unit-2.

Figure 13. Thin subaerial flows of basalt (Tev-2) exposed in the West Fork of Elk Creek in the Timber quadrangle. Tops and bottoms of individual flows exhibit brecciation, and thin reddish baked zones are common between flows.

Figure 14. Hillside of subaerial Eocene volcanic rock (Tev-2) along the Wilson River (sec. 35, T. 1 N., R. 6 W.) in which bands of vegetation define horizontal bedding. Several flows are exposed in the road cut.

Exposures in the southern Enright and northern Blaine quadrangles are dominated by massive flows of zeolite-cemented lapilli tuff and tuff breccia. The angular fragments of the tuffs and breccias are composed of aphanitic greenstone (Figure 10). Dense flows of fresh, massive, dark-gray pillow basalt are well developed locally. Exceptional exposures are present on the lower reaches of the Wilson River and on the Hembre Ridge (Figures 11 and 12). The relative proportion of sedimentary rock in the unit appears to increase towards the south in the central and southern parts of the Blaine quadrangle.

At least 2,000 feet of subaerial flow-on-flow basalt dominates the section in the Timber quadrangle (Figures 13 and 14). Individual flows average 10 to 20 feet in thickness and are characterized by reddish lower baked zones, vesicular to scoriaceous upper surfaces, and remarkable lateral persistence. The basalt is dense, aphanitic to porphyritic, greenish black, and in places displays remarkable columnar jointing (Figure 15). Locally near the base of the subaerial flow section are a variety of atypical breccias and other volcanic rocks of uncertain origin. One specimen consisted of 25 percent zeolite amygdules, 10 percent pyroxene phenocrysts, 5 percent reddish lithic fragments, and 60 percent light-gray groundmass. Similar rocks are exposed locally along the Salmonberry River in the northwestern Enright quadrangle (R.K. Perttu, oral communication, 1972).

Eocene volcanic rock unit-2 is late Eocene in age. It overlies undifferentiated Eocene sedimentary rock with Yamhill affinities in the Wilson River Canyon and overlies strata from which late Eocene foraminifers have been recovered near Blaine. Latest Eocene Cowlitz megafossils are associated with rocks assigned to the unit in the Birkenfeld quadrangle (Warren and others, 1945). Eocene volcanic rock unit-2 is believed to unconformably overlie sedimentary rocks (Tesu) in the Wilson River Canyon.

Figure 15. Columnar jointing in Eocene volcanic rock unit-2 along the east side of Drift Creek in the upper reaches of the Wilson River Canyon. Columnar jointing is indicative of a subaerial origin.

Eocene volcanic rock unit-3 (Tev-3)

Included in this unit are up to 3,000 feet of latest Eocene basalt exposed north of the Sunset Highway in the Birkenfeld and eastern Saddle Mountain quadrangles. Although regional relationships have been variously interpreted, it is here believed that the volcanic rock is situated stratigraphically above Eocene volcanic rock unit-2 and that it is separated from it by 500-1,000 feet of undifferentiated Eocene sedimentary strata (Tesu). The exposures were included in the Tillamook Volcanic Series by Warren and others (1945) and were treated as upper Eocene basalt (Teub) by Wells and Peck (1961). Van Atta (1971) treated the exposures as part of the Goble Formation.

Within the unit the main rock types include dark-gray to black porphyritic and nonporphyritic submarine and subaerial basalt flows and pyroclastic deposits. Five miles upstream from Jewell on the north bank of the Nehalem River subaerial mudflow breccias consisting of a crumbly matrix and large clasts of dike rock, volcanic rock, and baked sedimentary rock are exposed. Along the Sunset Highway the undifferentiated Eocene sedimentary rock unit is intruded with basaltic dikes and sills of all sizes, the larger dikes probably fed the late Eocene volcanism represented by the Tev-3 unit.

A latest Eocene age is interpreted for the Eocene volcanic unit-3 on the basis of the abundant Cowlitz-age fossils recovered from the sediments which underlie it. The exposures are similar to the volcanic accumulation at Cascade Head which also overlies latest Eocene strata and straddles the Eocene-Oligocene time boundary. Eocene volcanic rock unit-3 is overlain with probable conformity by Oligocene to Miocene sedimentary rock (Toms).

Oligocene to Miocene sedimentary rock (Toms)

Oligocene to Miocene sedimentary rock (Toms) is widely exposed in the northern Birkenfeld, central Saddle Mountain, and southern Svensen and Cathlamet quadrangles. The rocks were previously mapped as "Tertiary Shales" by Warren and others (1945) and as "marine Miocene sedimentary rock," and a variety of upper Eocene through Oligocene sedimentary rock units (Keasey, Cowlitz, and Pittsburg Bluff Formations) by Wells and Peck (1961). The unit is a continuation of the Oligocene to Miocene sedimentary rock unit of Schlicker and others (1972) in coastal Tillamook and Clatsop Counties. Available fossil data and map data indicate that strata at the base of Saddle and Humbug Mountains incorporated into Toms in this report may actually be equivalent to the younger Astoria Formation.

Oligocene to Miocene sedimentary rock in coastal Clatsop and Tillamook Counties is at least 5,000 feet thick (Schlicker and others, 1972) and a similar thickness is interpreted for the unit in inland Clatsop County. Low in the section the unit consists of well-bedded clayey siltstone with occasional concretions and concretionary horizons. Thin interbeds of arkosic, friable sandstone are also developed in places. Medium-gray, massive siltstone dominates upsection. The Oligocene to Miocene sedimentary rock unit is the least resistant to weathering of all units in the mapped area; it is characterized by a subdued topographic expression except in the immediate vicinity of intrusions.

An Oligocene age is indicated for most of the Oligocene to Miocene sedimentary rock by the numerous fossil collections recorded by Warren and others (1945). Stratigraphic position above the latest Eocene volcanic rocks of this paper is also consistent with such an interpretation. Astoria megafossils recovered from the base of Saddle Mountain by Warren and others (1945) and middle Miocene microfossils also recovered from near the base of the peak (Layfield, 1936b) suggest that Astoria-age strata are present immediately beneath the protective cover of middle Miocene volcanic rock which makes up the peaks.

The map distribution of the Miocene volcanic rock (Tmv) in conjunction with the inferred presence of Astoria strata at the base of Saddle Mountain and possibly Humbug Mountain suggests an unconformity between mudstones of Oligocene and early Miocene age and the Astoria Formation. The Astoria-age strata directly overlie older strata of probable middle Oligocene age. An unconformity beneath the Astoria Formation is also interpreted at various localities along the Oregon coast (Snavely and others, 1969; Schlicker and others, 1972). In this report local exposures of fine-grained Astoria-age strata are included in the Toms unit because they conform to the general concept of Oligocene and Miocene sedimentary rock, and their precise distribution is not known.

Middle Miocene sandstone (Tmms)

The middle Miocene sandstone consists of all the mappable sandstone which immediately underlies the Miocene volcanic rock in the Svensen and Cathlamet quadrangles. A large exposure is located in the middle reaches of Big Creek (Figure 16) and a smaller exposure is present 1 mile south of Westport (Figure 17) in the Cathlamet quadrangle. In addition, strata mapped as upper Miocene sandstone (Tmus) on the upper west slopes of Wickiup Mountain by Schlicker and others (1972) are here included in the middle Miocene sandstone (Tmms) on the basis of stratigraphic position.

The middle Miocene sandstone consists of massive beds of friable, medium- to coarse-grained, arkosic sandstone. Individual beds greater than 50 feet in thickness are common. No fossils are present and a littoral, possibly sand-bar origin, is inferred. A total thickness of several hundred feet is likely.

The precise stratigraphic relationships of the middle Miocene sandstone are uncertain. The unit may be equivalent to the Astoria Formation of Snavely and others (1969) as suggested by its stratigraphic occurrence directly beneath basalts of late Yakima and Yakima petrographic type (Snavely and others, 1973). Equivalence with the Scappoose Formation exposed farther to the east is also possible. Equivalence with the "sandstone of Whale Cove" of Snavely and others (1969) is not likely.

Miocene volcanic rock (Tmv)

Volcanic rock of Miocene age forms extensive exposures along the Columbia River in the Cathlamet and Svensen quadrangles and composes the bulk of Saddle Mountain and Humbug Mountain in the Saddle Mountain quadrangle to the south. The exposures were treated as part of the Columbia River lava by Warren and others (1945) and as Miocene intrusive rock and middle Miocene basalt by Wells and Peck (1961).

The exposures along the Columbia River consist of up to 1,400 feet of dense, tholeiitic, flow-on-flow basalt of subaerial origin in the vicinity of Bradley State Park and at Nicolai Mountain. Only the basal portions of some of the lowermost flows are pillowed or otherwise show signs of subaqueous conditions in these areas. Northwestward in the lower reaches of Big Creek and westward along the crest of Wickiup Mountain, breccias and pillow lavas are the dominate lithology (Figure 18). Intercalations of marine sedimentary rock are also common locally. A northeast-trending middle Miocene strandline is tentatively postulated in the Big Creek area.

Petrochemically the flow-on-flow basalts exhibit both late Yakima (Kienle, 1971; Snavely and MacLeod, 1973) and Yakima (Snavely and Macleod, 1973) affinities. Flow directions of the upper flows at Bradley State Park (late Yakima) are to the west according to Kienle (1971).

The exposures at Humbug and Saddle Mountains consist of a maximum of 1,300 feet of massive, submarine, basaltic breccia and palagonitic basaltic breccia cut by innumerable thin vertical dikes which display remarkable columnar jointing in places. The breccias are the dominant lithology and consist of glassy, fine-grained basaltic fragments of Yakima petrology (MacLeod, oral communication, 1972) set in a matrix of finer volcanic debris and glass.

The breccias at Saddle Mountain and Humbug Mountain have been variously interpreted as more or less local accumulations (Layfield, 1936b) and as localized remnants of a once far more extensive basaltic breccia blanket (Baldwin, 1952). The numerous dikes throughout the interior of Clatsop County are consistent with the view that the breccias and flows were originally of far greater extent than they are at present. The clustering of dikes at hill 1794 two miles south of Humbug Mountain suggests at least that a third local accumulation of Miocene basaltic breccia was originally present in that area.

The Yakima petrology (N. S. MacLeod, oral communication, 1972), of the Miocene basaltic breccias and their position above fossiliferous strata of middle Miocene age suggest that the unit is middle Miocene in age and has an absolute age of approximately 14 to 16 million years.

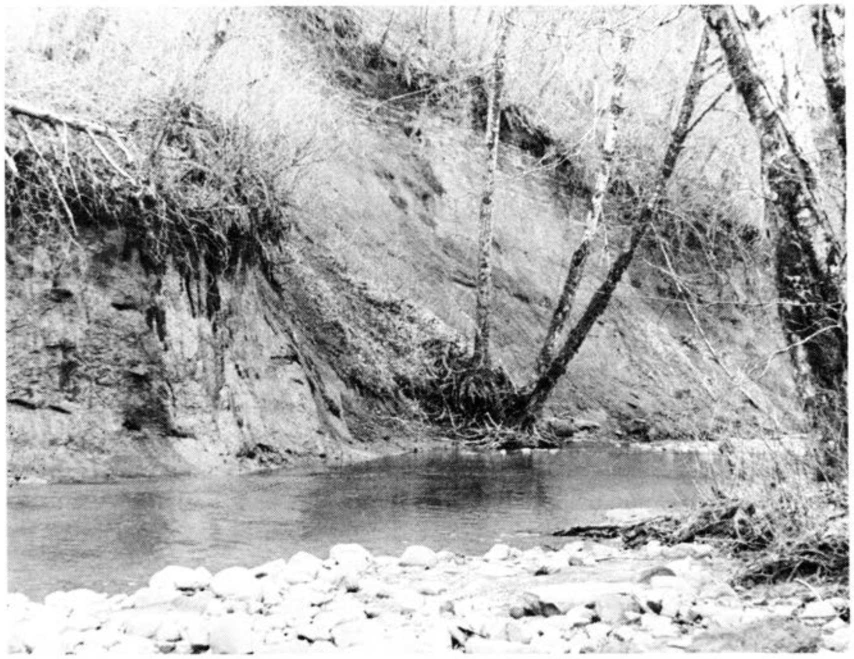


Figure 16. Massive arkosic sandstone of the middle Miocene sandstone (Tmms) exposed in the middle reaches of Big Creek (sec. 3, T. 7 N., R. 7 W.). Concretionary horizons define a gentle northerly dip.

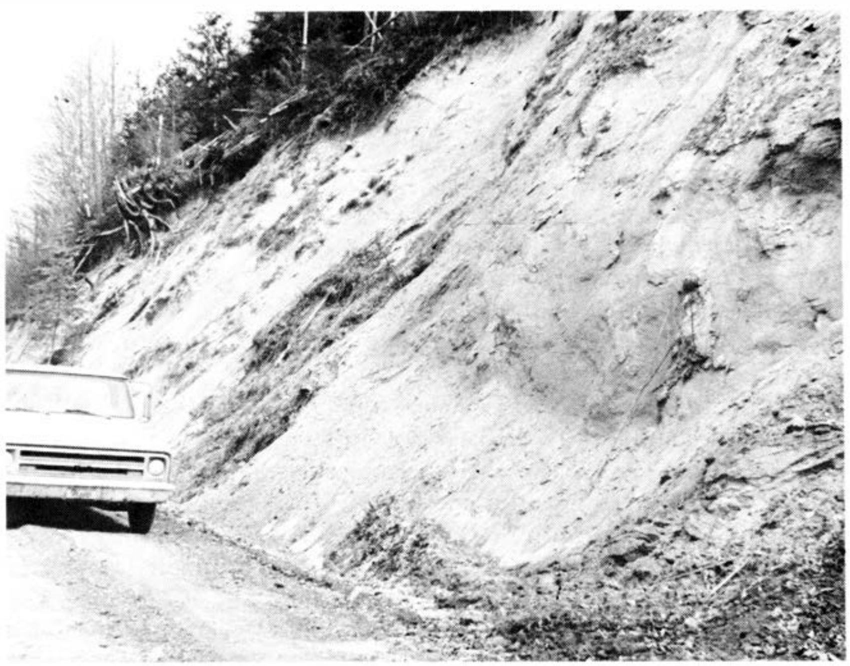


Figure 17. Massive, semi-friable, arkosic sandstone of the middle Miocene sandstone (Tmms) cropping out immediately beneath Miocene volcanic rock (Tmv) in the ridge south of Westport (sec. 2, T. 7 N., R. 6 W.).

Figure 18. Pillow structures developed in the Miocene volcanic rock (Tmv) in the lower reaches of Big Creek (sec. 29, T. 8 N., R. 7 W.). An underwater environment of cooling is inferred for the lavas. The resulting quarry rock is poor in quality.

Upper Miocene sandstone (Tmus)

The upper Miocene sandstone (Tmus) consists of 500 to 1,000 feet of consolidated sandstone and minor siltstone and overlies the Miocene volcanic rock (Tmv) in the northern Svensen (Figure 19) and Cathlamet quadrangles. The lower parts of the unit are interbedded with the upper parts of the Miocene volcanic rock at Bradley State Park, along the lower reaches of Hunt Creek, and on the upper slopes of Nicolai Ridge and Nicolai Mountain (Figure 20).

The upper Miocene sandstone is equivalent to part of the Astoria Series of Arnold and Hannibal (1913), part of the Miocene Series of Washburne (1914), the Pliocene (?) sandstone of Warren and others (1945), and the Pliocene marine sedimentary rocks of Wells and Peck (1961). It is equivalent to the upper Astoria Sandstone of Lowry and Baldwin (1952), and the Pliocene (?) sandstone of Dodds (1963, 1970). Strata mapped as part of the upper Miocene sandstone by Schlicker and others (1972) high on the west slopes of Wickiup Mountain are here considered to be part of the middle Miocene sandstone (Tmms) on the basis of stratigraphic position.

The lower parts of the upper Miocene sandstone consist primarily of friable, coarse- to medium-grained, massive, arkosic sandstone. Subaqueous slump breccias composed of randomly oriented mudstone slabs floating in a sandstone matrix are present at Clifton, Bradley State Park, and at the Gnat Creek Forest Park (Figures 21 and 22). The unit as a whole appears to be transgressive and passes upsection into clay-rich, finer grained, thinner bedded sandstones and siltstones in the vicinity of Aldrich Point. A greater tendency for mass movement in this area is attributed in part to the change in lithology.

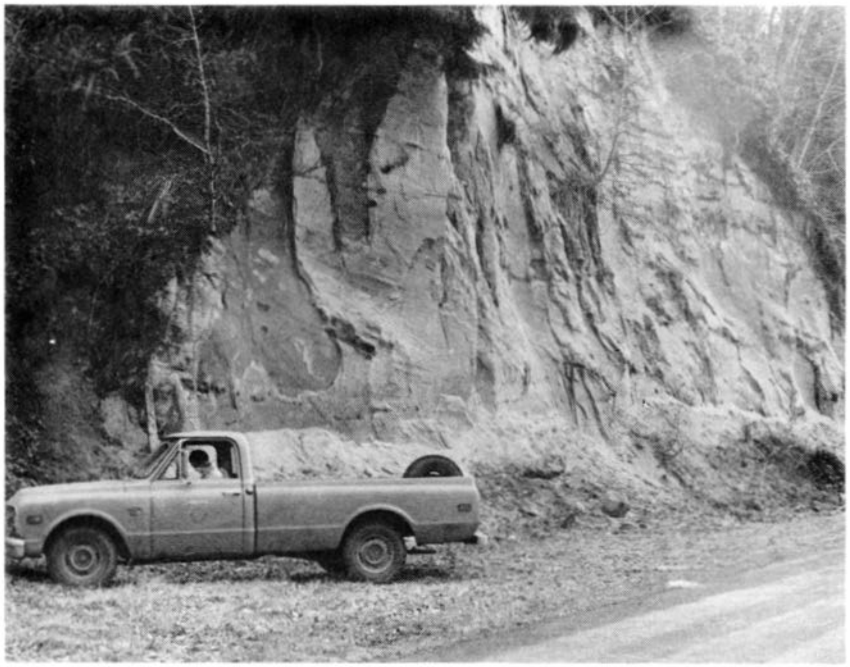


Figure 19. Massive arkosic sandstone of the upper Miocene sandstone (Tmus) exposed along the Columbia River near Knappa Slough (sec. 8, T. 8 N., R. 8 W.). The unit lies stratigraphically above the Miocene volcanic rock (Tmv).

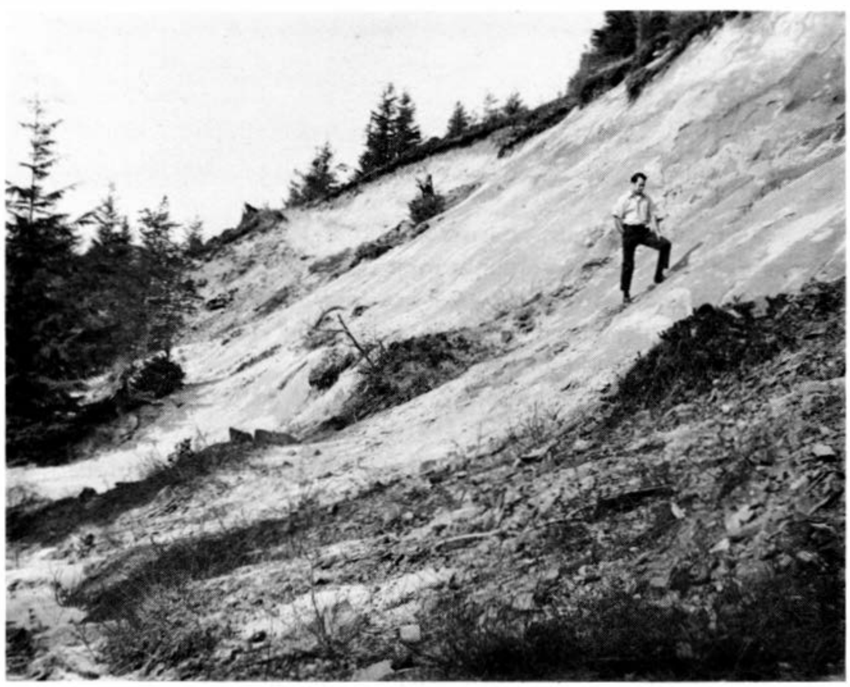


Figure 20. Interbed of upper Miocene sandstone (Tmus) in the upper part of the Miocene volcanic rock (Tmv) high on the slopes of Nicolai Mountain (sec. 8, T. 7 N., R. 7 W.).

Figure 21. Blocks of thinly bedded sandstone set in a friable massive matrix of coarser grained sandstone in the upper Miocene sandstone (Tmus) at Gnat Creek Forest Park. These features are interpreted to be subaqueous slump breccias.

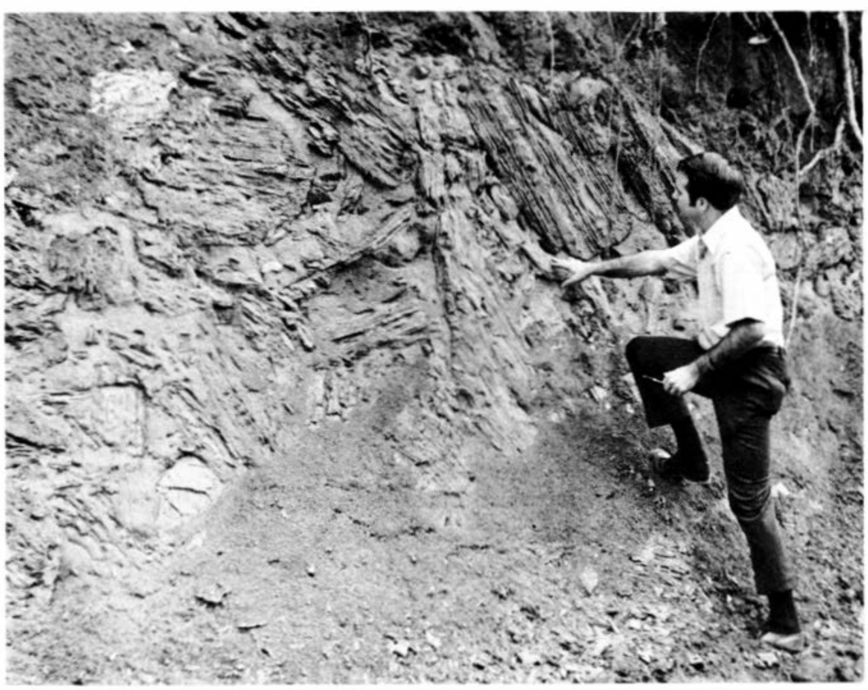


Figure 22. Additional subaqueous slump breccias at Gnat Creek Forest Park. Similar features are widespread in the lower part of the upper Miocene sandstone; undercutting by current action in an estuarine environment may be a possible explanation of their origin.

A brackish, possibly estuarine, environment of deposition is postulated for the upper Miocene sandstone. The coarse grain size and widespread slump breccias of the lower parts of the unit indicate appreciable current action. Interbedded subaerial basalt near Bradley State Park and on Nicolai Ridge indicate shallow water to continental conditions. The total absence of fossils suggests that the environment may not have been marine.

The upper Miocene sandstone is conformable over middle Miocene basalt having late Yakima affinities (Snavely and others, 1973) and it is late Miocene in age. Between Clifton and Brownsmead the unit underlies strata tentatively assigned to the Troutdale Formation with possible disconformity (Lowry and Baldwin, 1952).

Tertiary intrusive rock (Ti/Tic)

All the mappable intrusive bodies of the study area are included in this unit. Where the intrusions consist of a complex mass of dikes and interspersed unmappable sedimentary rock, mapping of the individual contacts was not attempted and the entire complex is referred to as an intrusive complex (Tic). Intrusions within volcanic terrains are difficult to delineate in reconnaissance studies and therefore are here treated as part of the volcanic units in which they occur.

On the basis of lithology and location of occurrence, the intrusive bodies are easily grouped into two major episodes of magmatic activity, Miocene and Eocene. Miocene intrusions are limited primarily to Clatsop County and consist of dense, hard, aphanitic dikes and sills. Many of the dikes are grouped in clusters around Saddle Mountain, Humbug Mountain and hill 1794 two miles south of Humbug Mountain. In addition, many of the larger dikes such as those at Flagpole Ridge, Boiler Ridge, and Fishhawk Falls define regional northeasterly structures. Many of the smaller intrusions throughout the middle Tertiary shales are not indicated on the map owing to their small size.

Eocene intrusions are mapped within the undifferentiated Eocene sedimentary rock unit along the Nestucca, Trask, and Wilson Rivers and along Sunset Highway in the Birkenfeld quadrangle. They consist primarily of dense, black basaltic rock, but also include coarse-grained gabbro. They generally contain scattered dark phenocrysts of pyroxene. Spheroidal weathering is common. Some of the rocks mapped as intrusives may, in fact, be volcanic in origin.

In the southeastern Enright quadrangle at Fox Creek, Hembre Ridge, and Archer Road, (Figure 23) dense dikes of greenish-black phaneritic basalt are widespread and are largely responsible for the steep slopes within the sedimentary section. Although parts of the major dikes are indicated on the geologic map, the total extent of the intrusions is much greater. In this area stratigraphic contacts between the volcanic rock units and the sedimentary rock units are unclear and structures are uncertain.

A short distance to the west at the bottom of the canyon at the "bend of the Wilson River", several hundred feet of igneous rock are interpreted to be intrusive in origin. Sediments in the river bottom are extremely baked, numerous sills and dikes are present in the river bed (Figure 7), and coarse-grained gabbroic boulders are present in the stream bed immediately downstream. In addition, cross-cutting relationships are apparent in the cliff face.

Along the Nestucca River numerous bodies of dense intrusive rock are exposed and are utilized as quarry rock. The intrusions apparently were a source of Tev-1 and Tev-2 volcanism. To the north along Sunset Highway much of the dike rock is aphanitic and not porphyritic. It is not distinguishable megascopically from intrusions of Miocene age elsewhere. However, location within Eocene terrain beneath Tev-3 volcanic units and association with numerous smaller intrusions of known Eocene age favor an Eocene age. Also, spheroids of dense, phaneritic basalt weathering out in places resemble Eocene dike rock observed in the southeastern Enright quadrangle.

Quaternary terrace deposits (Qt)

Alluvial terraces of elevated, flat-lying bodies of unconsolidated river sediments line the major streams of the mapped area including the North Fork of the Nehalem River (Figure 24), the Wilson River, the Trask River, and the Nestucca River. The alluvial terraces were formed in late Pleistocene times when

Figure 23. Spheroidal weathering developed in dense basaltic sill rock along Archer Road overlooking Jordan Creek in the Wilson River drainage (sec. 28, T. 1 N., R. 7 W.). Spheroidal weathering differs structurally from pillow structure primarily in its concentric, rather than radial, jointing.

Figure 24. Alluvial terraces in the upper reaches of the Nehalem River. Danger of stream overflow in times of flooding is minimal in most of the study area owing to the widespread terraces in the valleys.

uplift of the land relative to base level accelerated erosion, causing the rivers to cut downward through their flood-plain deposits.

The deposits consist of varying proportions of poorly sorted, indistinctly bedded sand, silt, and clay with interbeds of basaltic pebbles and cobbles. Gravels are most abundant in the terraces of the Wilson and Trask Rivers, where gradients are steep and streams are draining predominantly volcanic terrain. Thicknesses of the deposits are uncertain but probably do not exceed 50 feet in most areas. The upper surfaces of the terraces are generally a few tens of feet above river level during periods of low discharge. Some of the terraces in the upper reaches of the North Fork of the Nehalem River are 50 feet or more above river level.

Quaternary alluvium (Qal)

Young alluvium predominates in the lowlands along the Columbia River estuary and in the lower reaches of its major tributaries including Big Creek, Fertile Valley Creek, and Gnat Creek. Thickness of the deposits increases away from exposures of bedrock and varies from a few feet to possibly as much as one hundred feet in some places. No direct measure of the thickness of the deposits through the use of well logs was made, however.

The alluvium is composed primarily of sand and silt, but includes gravel in the Big Creek and Gnat Creek areas. Both creeks drain nearby regions of basaltic bedrock. Areas of peat development in the northeastern part of the Svensen quadrangle are shown on the geologic hazards map. It is emphasized, however, that peat may be present anywhere in the subsurface in areas underlain by alluvium.

Geologic Structure

The crust of northwestern Oregon is probably very thin, not exceeding 16 kilometers in thickness in places (Berg and Thiruvathukal, 1967a). Resistivity studies indicate that it is primarily oceanic in character (Cantwell and others, 1965). Recent theories of plate tectonics suggest that it may represent Eocene sea floor that has been welded to the continent. There may be no rocks older than Eocene in the subsurface of this part of the state.

The core of the Oregon Coast Range forms the backbone of much of the study area and is interpreted to be a broad upwarp. It is generally described as a north-plunging anticline, a view which overlooks some details, but which does explain many fundamental features. To the south the oldest stratigraphic unit of the study area (Tev-1) is exposed low in the canyons of the middle part of the Nestucca drainage. In the Wilson River drainage to the north late Eocene volcanic rocks (Tev-2) cap the ridges and older sedimentary rocks (Tesu) are exposed in the canyons. To the east and west north-striking sedimentary and volcanic rocks of younger age occupy the limbs of the anticline. Farther north along the Columbia River north-dipping volcanic (Tmv) and sedimentary (Tmus) strata of middle and upper Miocene age respectively cap the ridges and occupy the nose of the anticline.

A short distance east of the mapped area a sharp break in gravity contours is oriented north-south (Berg and Thiruvathukal, 1967b) and separates the Willamette Valley from axial parts of the Coast Range. A fault of regional proportions in the subsurface may cause this abrupt anomaly. In the western part of the mapped area in the lower Wilson, Trask, and Nestucca Rivers a fault is indicated between exposures of late Eocene volcanic rock (Tev-2) on the west and exposures of undifferentiated Eocene sedimentary rock (Tesu) on the east. Available attitudes and the abrupt change of lithology across the faults tend to rule out simple folding or facies change. In addition, the north-south alignment of the middle reaches of the Wilson River in the Enright quadrangle, and the South Fork of the Trask River and Niagara and Clarence Creeks in the Blaine quadrangle may signal a fundamental north-south structural break in the Eocene terrain of this part of the Oregon Coast Range.

Along the Sunset Highway in the Birkenfeld quadrangle, exposures of Eocene volcanic rock unit-2 form a northwest-trending linear ridge which overlooks the highway from the south. Apparently the volcanic rocks were upfaulted relative to the stratigraphically higher sedimentary rocks (Tesu) which underlie the valley in which the highway is situated. Faceted spurs along the escarpment and regional geologic relationships tend to support such a conclusion. North of the highway additional exposures of volcanic rock probably representing an even higher stratigraphic level (Tev-3) are exposed north of a complex northwest-trending contact. It is suggested that these rocks, covering approximately 30 square miles, were down-faulted relative to the sedimentary rocks along Sunset Highway.

The anticlinal structure is highly complex in its core areas. In the northeastern Blaine quadrangle where northerly strikes would be expected, the dominate strike is to the northwest and the dip is to the southwest. Strikes in the Trask River are aligned east-west and dips of 20° to the south are common. To the north near Jewell, Eocene volcanic rock unit-2 (Tev-2) and Eocene volcanic rock unit-3 (Tev-3) terminate along strike against Oligocene to Miocene sedimentary rock (Toms). Faulting is the simplest mechanism capable of explaining this relationship. If future mapping should establish a facies change northwesterly along strike in this area, however, the fault can no longer be inferred.

Fundamental northeasterly trending zones of tension and fracture are also indicated by major alignments of some of the middle Miocene basaltic dikes in the northern part of the mapped area. One series of dikes extends from Flagpole Ridge in the central Saddle Mountain quadrangle to Nicolai Mountain in the Cathlamet quadrangle.

Several periods of deformation are inferred for the study area. The unconformity within the late Eocene sedimentary and volcanic strata records moderate tectonism. An early Oligocene unconformity is suggested between the Keasey Formation and the Pittsburg Bluff Formation (both Toms of this report) by Warren and others(1945). An unconformity beneath Astoria-age strata in the Saddle Mountain area provides additional documentation for the middle Miocene period of uplift postulated by Snavely and others (1969) elsewhere. Middle Miocene tension and volcanism produced the extensive breccias and dikes of that age. Subsequently broad uplift has tilted the middle Miocene volcanic rocks(Tmv) and the upper Miocene sandstone (Tmus). Considerable erosion of these units is indicated by their abrupt truncation on the south slopes of Nicolai Mountain.

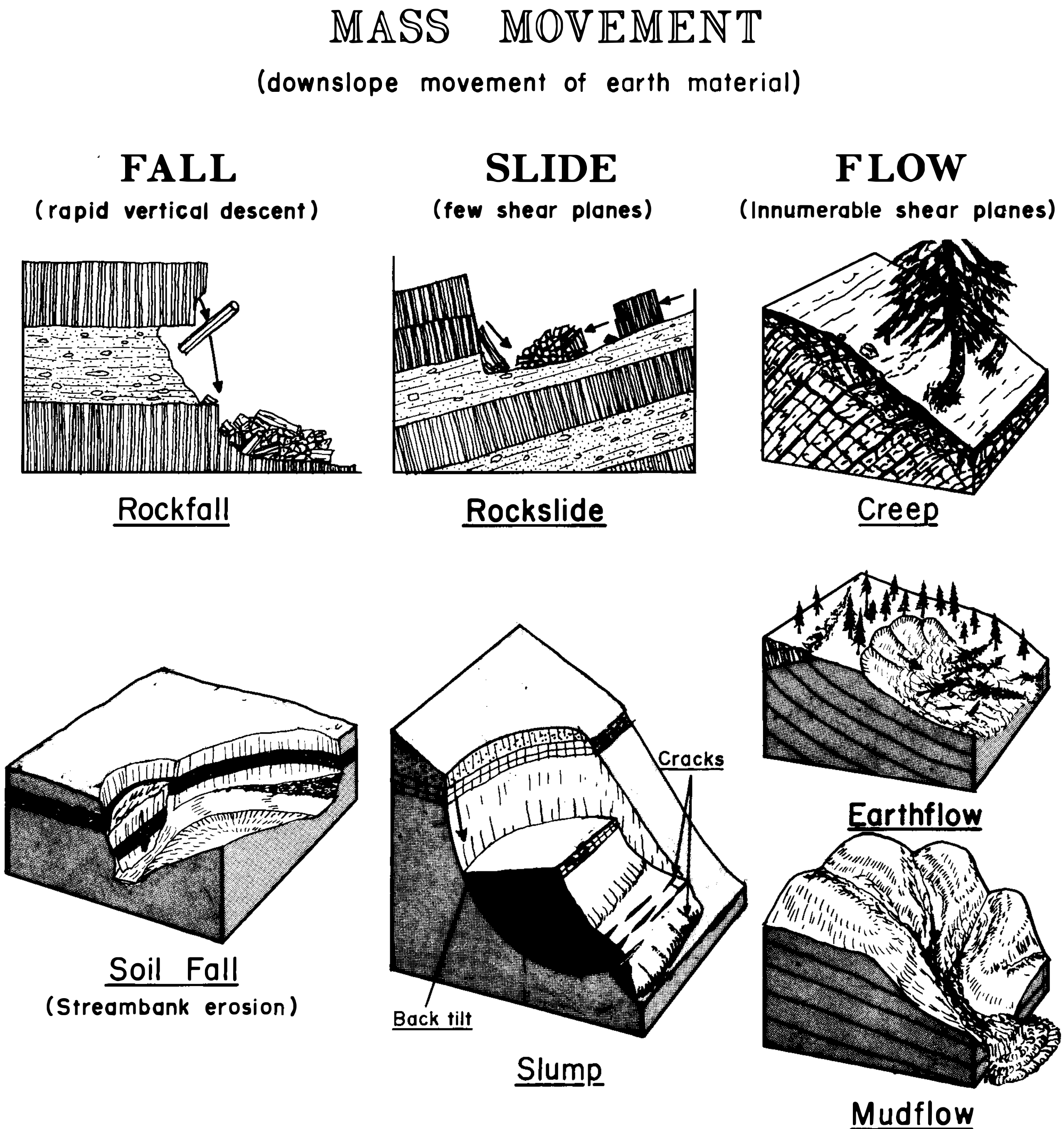


Figure 25. Diagrams of various types of mass movement.

GEOLOGIC HAZARDS

Land everywhere is constantly undergoing attack by the closely interrelated processes of weathering, mass wasting, and erosion. Physical and chemical weathering break down the bedrock to form soil and a variety of gravity-induced mass wasting processes transport the soil downslope to the streams and rivers, which ultimately carry it to the sea. Because the works of man generally require stable foundations, these geologic processes constitute real hazards to his activities.

Areas of steep slope, landslide topography, weak sedimentary rock or unfavorable geologic structure can become unstable with a minimum of excavation. Areas shown to exhibit any of these features on the maps should be viewed accordingly.

Areas of mass movement topography are inherently unstable and are especially sensitive to modifications of drainage and slope. Urbanization, and the installation of septic tanks, drain fields, large structures, and excavations in these areas should be carefully evaluated prior to development.

Areas of flash flooding, mudflows, active landsliding, and stream-bank erosion are especially critical, and particular attention should be paid to them in the planning process. Many of these areas may have to be withdrawn from development. Where necessary structures such as roads cross these features, provisions should be made to assure that they are engineered to accommodate the potential hazards.

Geologic hazards should be evaluated on a site-by-site basis. Such treatment was not feasible in this report, however, owing to the regional scope of the project. Hazards indicated on the map and statements made in the text, therefore, should be considered as preliminary.

Mass Movement
(Landslides and related processes)

Downslope movement of earth material under the influence of gravity has occurred extensively in the mapped area and has resulted in significant stability problems. Shallow slumps, rapid earthflows, rockfalls, and mudslides characterize steep slopes; degree of slope is therefore indicated on the geologic hazards map. In areas of gentler slope, mass movement can also occur. In these areas, a variety of topographic features commonly allow more precise delineation of the boundaries of the unstable areas. A pattern of triangles on the geologic hazards maps designates those areas in which mass-movement topography is apparent.

Terminology

Owing to the complex interrelationships involved in the various mass wasting processes, and the intergradations between them, a jumble of overlapping and sometimes contradictory terms has developed over the years to describe them. For the sake of clarity, therefore, terms and concepts used in this investigation are discussed below.

The term mass movement applies to all mass wasting processes. Areas of mass movement topography are areas which have failed in numerous small slides over a prolonged length of time.

Sharpe (1960), in a masterly treatment of the subject, analyzed mass wasting processes in terms of the specific type of movement, the rate of flow, and the water content. He arrived at three basic concepts of downslope movement: falls, slides, and flows; he further subdivided these into the specific types of mass movement. Falls include all types of downslope movement of earth material or rock which involve rapid motion through the air or tumbling motion down steep slopes. Slides involve movement along one or a few shear surfaces and include such phenomena as slumping. Flow, the third type of movement, involves internal movement along innumerable permanent and transient shear surfaces so that the overall downslope migration of material resembles that of a highly viscous fluid (Figure 25).

In terms of area affected, flow is the most significant type of mass wasting in the study area. It includes soil creep, earthflow, and mudflow. Soil creep is the slow, imperceptible, particle-by-particle downslope movement of unconsolidated debris in response to gravity. Frost heaving, expansion, and contraction with variations of temperature and water content, animal activity, and chemical decay of rock matter are some of the specific processes contributing to soil creep. Favorable factors include a thick soil, a protective cover of vegetation, and adequate slope. Soil creep generally does not penetrate to depths greater than a few feet.

With increased water content, soil and weathered rock material become more mobile, and downslope movement may take the form of large masses which move downslope in response to gravity. Commonly such movements involve several tens of feet of soil, earth, and broken rock. They are referred to as earthflow.

Under certain conditions even more water may be added to the soil so that a mudlike slurry is produced. The resultant rapid movement of earth debris is termed a mudflow and is favored by intermittent heavy precipitation, steep slopes, sparse vegetation, and an abundance of unconsolidated debris. Mudflows tend to be recurrent in the same channel and generally follow periods of heavy rain.

Slides and falls also are significant mass wasting processes in the mapped area, especially on steeper slopes. Slump is a type of slide in which unconsolidated earth debris or bedrock moves downslope as a single unit along a curved basal slip plane so that the ground surface within the slide unit tilts back slightly towards the hill. The depth of penetration of slumps is usually greater than that of earthflows of similar areal extent. Other types of slide include debris slide, a downslope block-like movement without backward rotation, and rockslide. Rockfall and rockslide account for most of the talus slopes in the steeper parts of the mapped area, especially along the Wilson River.

The term landslide is perhaps the most confusing of all. To some it denotes downslope movement at a perceptible rate (Sharpe, 1960; Holmes, 1965; Bloom, 1969). As such it includes falls and many slides as defined above. To others it includes all downslope movement regardless of the rate of movement (Varnes, 1958; Schlicker and others, 1972). To the layman the former concept is perhaps the most widespread. Because this report will be used primarily by the layman for planning purposes, the term landslide is restricted to downslope movement of a rapid nature.

Recognition of mass movement

Areas of mass wasting are characterized by a variety of topographic features. An understanding of these features is a useful aid in assessing the particular stability problems of a given area. Creep, for example, generally is associated with smooth, rounded, convex hillsides. The trunks of trees growing in areas of soil creep are commonly smoothly curved downslope. In areas of urban development tilted fences, bowed sidewalks, and tilted telephone poles may be common.

Areas of earthflow ideally exhibit a steep scarp or pull-away zone at the head of the disturbance and a jumbled topography downslope. Sag ponds, irregular mounds, randomly tilted trees, and tension cracks are common. Slopes within the slide mass are gentler than those of the surrounding intact terrain. In regions of widespread earthflow, stream drainage is generally poorly developed.

Areas of slumping display many of the characteristics of earthflow including headscarps, sag ponds, and tilted trees. In addition a large raised area, or toe, marks the lower boundary of the arcuate shear zone in the subsurface. Also, backtilting associated with slumping results in a more pronounced headscarp and a relatively flatter terrain within the disturbed area.

In areas of slump and earthflow, the primary distinguishing features are easily obscured by vegetation and erosion. Consequently recognition of old slumps and earthflows is considerably more difficult. Generally hummocky terrain, irregular drainage, and anomolously low slopes relative to adjacent terrain of similar lithology characterize these areas. Roadcuts may expose jumbled rock debris of an otherwise obscured slump or earthflow.

Rockfall and rock slide are restricted to regions of relatively steep terrain. Recognition is generally straightforward and is based upon the presence of talus, overhanging ledges, and similar features. Vegetation may soon cover the talus, but the uniform talus slope at the base of a steep cliff is unmistakable.

Recognition of mass movement is somewhat subjective, and determinations should be based on as many criteria as possible, including field investigations and aerial photographic interpretations. Reliance on general topographic expression alone may be misleading. For instance, innumerable dikes cutting mudstone may present a topographically hummocky expression resembling mass movement. Likewise escarpments cut into firm volcanic bedrock overlying softer sedimentary rock may give an expression that resembles a giant pull-away zone or headscarp. To make a valid assessment of land stability, a knowledge of the local geology derived from as many sources as possible is desirable.

Causes of mass movement

Mass movement is the downslope movement of consolidated and unconsolidated earth material in response to gravity. Assisting gravity are a wide variety of other factors both regional and local in scale. Although many of these factors are beyond man's influence, many others are subject to practical human control.

Factors of mass movement of regional scope include climate and rock type. The climate of the study area is moist marine and is typified by heavy winter precipitation. The large amounts of water introduced into the ground aid in the chemical breakdown of the rocks, increase pore pressure, decrease shear strength within the rocks, and initiate a variety of mass wasting processes including earthflow, mudflow, and slump.

Rock type also plays a large role in determining the tendency of an area to slide. Whereas some rock units such as intrusive rock or basalt flows are extremely stable, other rock types such as clayey siltstone are prone to failure in wet climates. The combination of rock type and climate is fundamental in the inherent instability of much of the mapped area.

When ground water percolates through the earth, pore pressure is increased, ions are dissolved and carried away, and clays are saturated. All of these processes contribute to instability. By enhancing surface drainage, however, man can often increase ground stability. Conversely, lawn watering and septic tank drainage may locally decrease stability and initiate sliding in previously stable terrains. Rapid drawdown in water storage areas can cause slides within reservoirs.

Bodies of earth undergoing mass movement can generally be viewed in terms of a load area situated high on the slope which is being drawn downslope by gravity, and a toe area near the base of the slide which tends to retard further downslope motion through friction. Embankments and other forms of construction on potential load areas may initiate sliding, whereas slope reduction and benching may increase stability in some large cuts. Likewise, excavations on the toe of a landslide may trigger additional sliding, whereas the construction of buttresses or piling will increase stability.

Vegetation as a rule covers and binds the soil and removes moisture through transpiration and therefore is an inhibitor of mass wasting. Removal of vegetation by fire, logging, landscaping, or by a variety of other human actions may decrease stability significantly. Likewise drainage may be manipulated to either retard or enhance mass movement.

In all cases, individual site investigation followed by a balanced appraisal of goals and costs are required before a final decision can be made concerning the suitability of a particular site for a particular type of development. It is emphasized that areas of instability indicated in this study are based on a generalized regional study of natural conditions at the present time. Future activities of man as well as nature may be sufficient to alter the relative stability of individual sites.

Distribution of Unstable Land

The study area is made up of parts of basins of five major west-flowing rivers: Columbia, Nehalem, Wilson, Trask and Nestucca. Although each of the river basins is subject to land instability in a general sense, careful study shows that each basin can be characterized to a large extent by its own particular set of problems.

Columbia River valley

In the study area, the basin of the Columbia River is subdivided into two regions. The lowlands area adjacent to the river is underlain by a variety of sedimentary rock units primarily of post-middle Miocene age. They include Quaternary alluvium (Qal), terrace gravels (Qt), and upper Miocene sandstone (Tmus). Exposures of Oligocene to Miocene mudstone in the Wauna area are also included in the lowlands. The uplands are underlain by Miocene volcanic rock (Tmv) and older sedimentary strata. West of Bradley, U. S. Highway 30 forms an approximate boundary between the two regions.

Uplands: Miocene volcanic rock underlies most of the uplands area. It forms steep slopes and cliffs at Wickiup Mountain, gentle uniform slopes with thin soil cover on Nicolai Ridge, and more deeply weathered irregular terrain at Porter Ridge. On Wickiup Mountain, in the lower reaches of Big Creek, and on the east face of Nicolai Ridge, undercutting has produced steep slopes; rockfall and a variety of other slides and flows are a constant threat. On the west face of Wickiup Mountain maintenance of access roads is particularly difficult.

In contrast the gently sloping north side of Nicolai Ridge constitutes some of the most stable terrain in the study area. Mass wasting in the region is minimal. However, local pockets of deep weathering have produced thick layers of soil and decomposed bedrock. Farther to the south on Nicolai Mountain the presence of interbedded sandstone at the surface has introduced numerous slides of local extent. Poor drainage arising from one such slide a mile northwest of the summit of Nicolai Mountain has resulted in the development of extensive marshlands.

In the upper reaches of Big Creek older sedimentary rock is exposed beneath the Miocene volcanic rock which caps the ridges. Earthflow and slumping is widespread, and the terrain is among the most unstable in the study area (Figure 26). Large blocks of basalt are sliding slowly from higher elevations, detached clumps of unconsolidated soil and debris are widespread, and trees commonly rest uprooted on the slopes and in the canyons. Torrential flooding of the main channel and its tributaries has substantially undercut the stream banks in many places.

Along the east bank of Big Creek near the mouths of Pigpen and Mud Creeks (secs. 3, 10, 11, T. 7 N., R. 7 W.), relatively resistant middle Miocene sandstone (Tmms) forms steep slopes with a thin soil cover. Flash floods, mudslides, and earthflow have produced a series of scarred channels in various stages of development. Recently constructed access roads farther up the slope are continually threatened by the instability of this region and may, in fact, contribute to it by interrupting and diverting the drainage.

Lowlands: The lowlands arbitrarily include the flat areas of Quaternary alluvium, the rolling hills of upper Miocene sandstone (Tmus), and the slide area developed in Oligocene to Miocene sedimentary rock (Toms) near Wauna. The variety of landforms and rock types makes the region relatively complex.

The Wauna area is geologically unique in several ways. First, it is situated at a pronounced bend in the Columbia River; second, it is situated in a region in which relatively soft sedimentary rock is exposed beneath a cap of Miocene volcanic rock (Tmv); and third, fluctuations in the level of the Columbia River in approximately the last one hundred thousand years have exerted a profound influence on the landforms that we see today. Briefly, as the Columbia River has impinged on the east face of Nicolai Ridge during times of fluctuating river level, it has undercut the ridge to produce a complex series of slides. The slide mass is characterized by rolling topography, irregular drainage, and the abundance of basaltic and mudstone blocks set in a disordered matrix of unconsolidated debris.

Borings drilled at the site of the Wauna Paper Plant (Shannon and Wilson, Inc., 1964) for foundation investigations indicate the presence of slide debris in the subsurface to a depth of at least 156 feet. Intercalated with the slide debris are occasional interbeds of layered alluvium, a feature which suggests that the slide has undergone repeated movements over an extended length of time and was probably not the result of one catastrophic slide.

Depressions in the slide mass along the river bank served as sites for abundant vegetative growth during times of high water level. Today these sites are preserved as localized horizons of peat and organic soil in the subsurface. The compressibility of these materials constitutes a threat to development owing to their poor foundation capabilities. The actual slide mass is now probably inactive.

East of Wauna, drainage in the Oligocene to Miocene sedimentary rock (Toms) is well integrated and the bedrock observed in scattered outcrops appears intact. Evidence of extremely deep landslide failure similar to that at Wauna is lacking. Mass movement in the hills above Westport, for example, probably is restricted to moderate depths along the sides of individual ridges. Farther east in Columbia

Figure 26. Hazards in the Big Creek drainage include rockfall (which delivers large boulders downslope), stream flooding (which is indicated by stranded driftwood), and earthflow and soil creep (note the tilted tree).

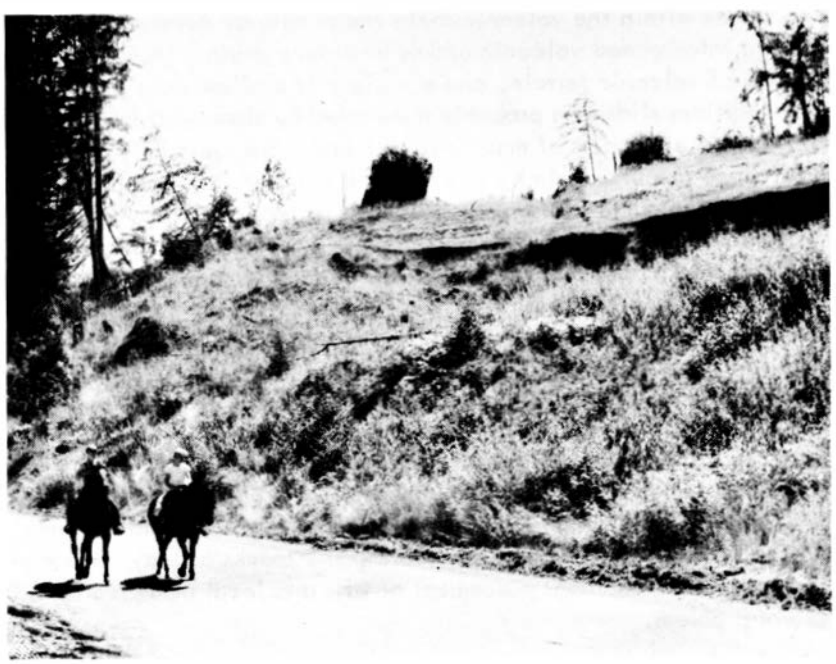


Figure 27. Slump features developed in Oligocene to Miocene sedimentary rock (Toms) along the Nehalem River. This unit is prone to sliding, especially where slopes are oversteepened by stream erosion or acts of man, such as highway construction.

County the lowland terrain gives way to steep canyons in firm bedrock, which were formed by tributaries to the Columbia River when it flowed at a lower elevation than at present.

West of Bradley and south of Aldrich Point, terrain underlain by upper Miocene sandstone (Tmus) is characterized by well-developed spurs in most areas and by shallow mass wasting in places. In the south the sandstone is relatively stable and commonly stands in steep slopes. To the north in the vicinity of Aldrich Point, the finer-grained upper parts of the upper Miocene sandstone are exposed and the tendency for failure is more pronounced. There slides are generally confined to the soil zone and probably do not penetrate to depths greater than 20 feet.

The alluvium in the vicinities of Brownsmead, Long Island, and Blind Slough is unconsolidated, saturated, and rich in organic material. It probably is not suitable for the construction of structures with high weight foundation loads. Areas of present-day peat formation are indicated on the geologic hazards map. It is emphasized that the distribution of peat in the subsurface is probably more extensive and that peat, because of its compressibility, is not a good foundation material.

Nehalem River basin

The basin of the Nehalem River can be subdivided into two natural regions in the study area. The southern part, which encompasses the southern half of the Saddle Mountain and Birkenfeld quadrangles and the extreme northwestern corner of the Enright quadrangle, is underlain primarily by volcanic rock. Areas to the north are underlain primarily by sedimentary rock.

Volcanic terrain: The bedrock in the southern region is resistant to erosion and is typically mantled by a thin veneer of residual soil. Canyons are commonly steep sided. In general terms, the bedrock is among the most stable in the study area. However, in regions of steep slope (see hazards maps) and undercutting, rockfall, rockslide, and slump may occur. In individual site examinations, attention should be aimed especially at interbedded sedimentary rocks, if present, for it is in them that many land stability problems originate.

West of the Nehalem River in the general vicinities of Hamlet and Cougar Mountain in the Saddle Mountain quadrangle, slopes within the volcanic rocks are relatively gentle. The erosion surface rests upon gently north dipping interbedded volcanic and sedimentary strata. Here soil cover is somewhat thicker than in most areas of volcanic terrain, and a variety of shallow mass movement features are developed. Under natural conditions sliding is probably dominated by slow earthflow and soil creep. Oversteepening by excavation and other acts of man could initiate more rapid movement. West of the Nehalem River regions of gentler slope are underlain by intercalated volcanic and sedimentary rock. There, also, mass movement is more prevalent than in the predominantly volcanic terrain to the south.

Along Sunset Highway in the eastern Saddle Mountain and western Birkenfeld quadrangles, sedimentary strata within the Eocene volcanic pile are the site of several mass movement features. Immediately east of Jewell Junction several square miles of terrain exhibit low rolling topography and are undergoing active landslide movement. Repairs along this stretch of Sunset Highway are numerous. The toe of the slide is bounded by the Nehalem River and failure may be as deep as 50 feet. Owing to the size of the slide area and the direct influence of the Nehalem River, it is apparent that no permanent corrective measures for the entire slide area are feasible at the present time.

Farther east near the Washington-Tillamook County line (secs. 1 and 2, T. 3 N., R. 6 W.), Wolf Creek and its tributaries are undercutting Sunset Highway. Long cracks up to 1 inch in width extending along the highway indicate that the underlying ground is migrating slowly downslope. Because failure was initiated prior to the construction of the road, sealing the cracks as they appear probably would not offer even a temporary solution. Improper placement of fills and local modifications of drainage may both contribute to the present problem.

Sedimentary terrain: The northern parts of the Saddle Mountain and Birkenfeld quadrangles are underlain primarily by Oligocene to Miocene sedimentary rock. The unit is deeply weathered and extensively eroded to a characteristic low rounded topography. Numerous basaltic intrusions in the Saddle Mountain quadrangle form the resistant cores of most of the higher hills scattered throughout the area. In addition, thick layers of basaltic breccia make up the bulk of Saddle and Humbug Mountains, two of the higher topographic features in the Coast Range.

Physical and chemical decomposition is extensive in the Oligocene to Miocene sedimentary rock and weathering commonly penetrates to depths of 20 feet or more. Along ridge crests, however, fresh bedrock is commonly much nearer the surface. Soils of silt and clay with poor foundation characteristics are widespread. Well over half the region is undergoing mass wasting (Figure 27); major processes include earthflow, soil creep, and slump. Depth of movement probably does not exceed a few tens of feet in most areas.

The terrain is more stable in areas of abundant volcanic dikes. Along Sunset Highway immediately south of Humbug Mountain, intrusive basalt forms the core of many of the ridges; they are not prone to sliding. The basalt has baked some of the sediment to varying degrees, thus adding to its stability. An additional element adding to the stability of the highway in this area is the fact that it follows ridge crests. Because mass movement occurs on sloping surfaces and mountainsides, it is evident that ridge crests, by virtue of their location and gentle slopes, should be relatively stable.

River valleys: Flat-lying, unconsolidated terrace deposits of sand and silt occupy the main stream valleys in the northern and central parts of the Saddle Mountain and Birkenfeld quadrangles. Deposits of organic soil in regions of past or present poor drainage and the high water table during certain times of the year, however, may pose stability problems for structures. On-site investigations for large structures are advised.

A series of proposed dam sites has been tentatively investigated by the U. S. Geological Survey (Young and Colbert, 1965). They are the Squaw Creek site (secs. 4 and 33, T. 5 N., R. 6 W.), the Tideport site (secs. 23 and 24, T. 5 N., R. 7 W.), the Elsie site (sec. 4, T. 4 N., R. 7 W.), the Spruce Run site (sec. 24, T. 3 N., R. 8 W.), and the Salmonberry site (sec. 10, T. 3 N., R. 8 W.). Actual construction is not planned at the present time, owing in part to land acquisition and relocation difficulties. Subsequent investigations have considered not only land stability at the site of the dam but also the possibility of increased landsliding throughout the reservoir area. Young and Colbert (1965) have demonstrated that fluctuating water levels and water tables behind dams can be instrumental in initiating sliding in previously stable areas.

Wilson River basin

Rock distribution, vegetative cover, and soil thickness are highly variable in the Wilson River basin, and stream behavior is unpredictable. Consequently, mass wasting features are complex. To aid the discussion, the basin is subdivided into three segments.

Lower reaches: That part of the Wilson River which lies downstream from Zigzag Creek (sec. 4, T. 1 S., R. 8 W.) is treated as the lower reaches of the Wilson River drainage. The major rock type consists of hard massive volcanic breccia and pillow basalt. Soils are generally thin and slopes are steep. Runoff is rapid and mass movement in terms of areal extent is minimal. The steepness of the terrain, however, does favor rockfall and rockslide and there is constant danger of this sort of hazard at the base of most cliffs and slopes.

Locally, where soil cover is a few feet thick or more and slopes are steep, there is danger of catastrophic mudflow. In January 1965, after 8.65 inches of rainfall in a 48-hour period had generated a 100-year flood in the Wilson River, saturated debris from a ridge crest flowed rapidly downslope across State Highway 42 at a point 8 miles east of Tillamook (sec. 18, T. 1 S., R. 8 W.). The valley was dammed to a height of 60 feet (40 feet above road level), and water level rose at a rate of 1 foot every 10 minutes until a channel was formed and the lake was drained without incident. Subsequently, minor sliding blocked the highway for several hours in the winter of 1972.

The mudflow left a scar in the hillside which is visible to this day. A similar scar a short distance to the northwest trends east-west into the North Fork of the Wilson River (sec. 13, T. 1 S., R. 8 W.). Inasmuch as mudflows tend to recur several times within the same channel, these sites warrant observation.

Moreover, they are especially susceptible to future movement while vegetative cover is largely absent.

Mudflows of this sort are also favored by steep slope, thick soil cover, and heavy rains, none of which lend themselves to practical correction. Mudflows also tend to originate in channels of short length such as those along the lower reaches of the Wilson River. A sudden drop of discharge in the Wilson River during times of heavy rainfall and flooding may signal the development of a landslide dam upstream. Under these circumstances immediate evacuation is imperative.

Middle reaches: The stretch of the Wilson River extending from Zigzag Creek on the west to Moore Creek on the east (Sec. 2, T. 1 N., R. 7 W.) is here considered as the middle reaches of the Wilson River. The distribution of rock types and soils is particularly complex in this area.

Volcanic breccia and pillow basalt form resistant caps to most of the ridges. Downslope the valley walls consist of varying amounts of sedimentary rock, hard basaltic intrusive rock, and volcanic breccia. Slopes in the igneous rocks are steep to moderate and slopes in the sedimentary terrain are generally moderate owing to the widespread intrusions.

The major forms of mass wasting on the upper slopes consist of rockfall and rockslide where the capping volcanic strata stand in steep slopes or where they are being undercut. Heaps of volcanic rubble are common on logging roads at the bases of cliffs composed of volcanic rock. Tree-covered talus is widespread on many of the hillsides throughout the area.

The sedimentary rock is characterized by earthflow, slump, and soil creep in areas where intrusions and baking are not prevalent. Depth of failure is difficult to determine and is probably variable. Thickness of the slides probably does not exceed 50 feet, however, and in most areas of disturbance movement appears to be superficial. Steep slopes and ledges of firm bedrock are common within the sedimentary rock terrain.

Thickness of soil cover within the middle reaches of the Wilson River varies considerably. Soils developed upon the volcanic breccias constitute a thin residuum in some areas and are quite thick in others. Likewise soils developed atop the sedimentary rocks are locally quite thin as along Keenig Creek Road (sec. 25, T. 1 N. R. 8 W.). As a general rule, soils are thinnest along ridge crests, where thicknesses of a few feet are common, and they are thickest on the sides of hills. Depths of failure in slide areas probably follow a similar pattern.

Mass movement in the middle reaches of the Wilson River varies from rockfall and rockslide along the volcanic ridge crests to earthflow and slump in isolated patches of unsupported sedimentary rocks on the lower slopes. Sheets of talus are draped over bedrock in many areas, and thick vegetative cover blankets much of the terrain. Although much of the area is known to be unstable owing to the moderate to steep slopes, more precise analysis is difficult.

Upper reaches: The stretch of the Wilson River extending from Moore Creek eastward to the Tillamook County line is here considered as the upper reaches of the Wilson River. The major rock type consists of a series of hard to crumbly subaerial basalt flows. Interbedded sequences of tuffaceous volcaniclastic fine-grained sedimentary rock are recognized.

North of State Highway 6 the subaerial flows form steep cliffs of exposed bedrock mantled in places with rocky debris derived from higher elevations. Rockfall and rockslide are the major mass wasting processes. Soil cover is minimal owing to the intense rainfall in the winter months, the heavy runoff, and the lack of vegetative cover due in part to the forest fires of the 1930's. Bouldery rubble derived from rockfall is heaped upon parts of most of the logging roads. Although the steep slopes are relatively stable from a geologic standpoint, they are dangerous from a human point of view.

Sedimentary rock north of the highway occupies dip slopes immediately east of the steep exposures of volcanic rock. Small canyons cut into the sedimentary rocks are generally rather steep. It is apparent that the rock is relatively stable even though creep is recognized in some areas.

South of the highway much of the basaltic bedrock along the upper reaches of the Wilson River is rubbly and prone to rockfall and sliding. Corrective measures employed along the highway in sec. 35, T. 2 N., R. 6 W. have included pulling loose debris down with bucket scraper and pry bars. Wire fencing on the slopes directs falls into ditches along the highway and keeps rubble off the driving surface.

Trask River basin

In this study the Trask River is subdivided into the lower reaches, located downstream from Samson Creek (sec. 22, T. 2 S., R. 8 W.), and the upper reaches, located upstream from that point. Basaltic breccia is the predominant rock type of the lower reaches, whereas the bedrock geology of the upper reaches is considerably more complex. There sedimentary rocks, intrusive rocks, and intercalated volcanic and sedimentary rock sequences are well represented.

Lower reaches: The lower reaches of the Trask River are characterized by steep slopes, impervious volcanic bedrock, and variable vegetative cover. Along the steeper slopes rockfall and rockslide have produced flanking deposits of talus. Where sedimentary interbeds are present, soil creep and surficial earthflow are operating. In the extreme lower reaches of the Trask, where sedimentary strata overlie the volcanic sequence, mass movement is much more widespread.

Many of the streams draining into the Trask occupy short steep channels in bedrock. As is true of the Wilson River, such channels have a potential for mudflow activity. Owing to the relative lack of soil and sedimentary rock, however, flash flooding is the most immediate danger. This is discussed in a later section.

Upper reaches: Bedrock along the upper reaches of the Trask River consists of bedded sedimentary rocks low in the canyons in the northern parts of the basin, and interbedded volcanic rock in the central and southern parts of the basin and high on the slopes in the north. Numerous igneous intrusions cut the sedimentary rock. Along the steeper slopes rockfall and rockslide are common occurrences. As elsewhere, areas prone to this type of activity are indicated on the hazards map by the steep slope color pattern. In regions of sedimentary rock or deeply weathered volcanic rock, earthflow and soil creep are widespread.

North of the Trask Guard Station tilted trees, disrupted drainage, sag ponds, and hummocky topography are indicative of pronounced mass movement on the ridge between the Trask and Wilson Rivers in the vicinity of the Trask cutoff road. Farther east, however, along the North Fork of the Trask River, numerous large intrusions are present in the sedimentary rock, and sliding is more restricted and localized.

The region south of the Trask Guard Station is characterized by moderate to steep slopes, complex intercalations of volcanic and sedimentary rock, a soil cover of highly variable thickness, and patchy vegetative cover. Conditions are favorable for localized mass movement and numerous slides are present.

During the winter storms of 1972, an earthflow spread into the Trask River (sec. 13, T. 2 S., R. 8 W.), blocking the flow of water temporarily and causing considerable damage to the road (Figure 28). Examination of the site reveals that the total slide mass is up to 1,000 feet wide and extends for almost 1 mile up the slope. It consists primarily of residual soil, sedimentary rock, and volcanic rubble. The toe of the slide is being undercut by the South Fork of the Trask River. The activity of 1972 was but one small episode in the downslope migration of a tremendous mass of material. With future flooding and undercutting, continued sliding is imminent (Figure 29).

Similar slides of varying sizes and degrees of development are present along all of the streams of the upper Trask River drainage. The sinuous courses of the rivers play a large part in the undercutting process. Many slide areas which have not undergone significant movement recently are modified to varying extent by stream erosion and gullying and are correspondingly more difficult to recognize.

Nestucca River basin

The drainage basin of the Nestucca River in the study area is characterized by interbedded volcanic and sedimentary rocks on the upper slopes and ridge crests, sedimentary rock with scattered intrusions on the middle slopes, and volcanic and baked sedimentary rock on the lower slopes of the canyons upstream from Blaine. Mass movement is localized and minor in the volcanic terrain and it is fairly widespread in the sedimentary terrain.

Figure 28. Gullies carved in the toe of the massive earthflow that partially blocked the Trask River in the January storms of 1972. The slide extends for one mile up the slope and will undoubtedly move again (sec. 13, T. 2 S., R. 8 W.).

Figure 29. Riprap in foreground acts to protect the road (not shown) from stream erosion, but it also directs stream flow against the toe of the slide. The degree to which this may induce future sliding on the far bank is unknown.

At the lower elevations downstream from Blaine earthflow and soil creep are common. A recent earthflow is located near Camelback Bluff and another is located a few miles north of Blaine on Moon Creek. Between Boulder Creek and Alder Creek gravel terrace deposits mantle older slide debris that apparently swept into the valley from the south. Soil and unconsolidated surficial debris throughout the area is several tens of feet thick in places. Exposures along the highway immediately downstream from Blaine, however, reveal that soil thicknesses are locally quite thin, especially on hilltops and along ridge crests. Mass movement probably extends to its greatest depths along the lower slopes, where penetration of several tens of feet is likely.

Observations on numerous logging roads north of the Nestucca River in the vicinity of Square Top reveal that soil cover is generally thin in the sedimentary rock terrain along the ridge crests. Smoothness of the hillsides downslope indicates that the major form of slope failure is soil creep. Locally, however, earthflow is indicated. Intrusive bodies of small size are scattered throughout the region.

The lower canyon walls of the middle and upper Nestucca drainage consist primarily of volcanic rock. Rockfall and rockslide are the major slide processes and constitute a minor geologic hazard. Earthflow and soil creep operate locally at the lower elevations where sedimentary rock and deep weathering horizons have yielded a thick unconsolidated cover. Intrusive bodies are abundant in the creek bed.

Flooding and Stream-bank Erosion

Significant flooding of the Nehalem, Wilson, Trask, and Nestucca Rivers is a minimal hazard in the study area owing to the well-developed terraces and deep channels in most of the valley areas. In addition, storm tides which greatly accentuate lowland flooding in the coastal areas are not a factor in the inland areas. The major dangers associated with running water in the upland areas include stream-bank erosion along the major streams and flash flooding in secondary streams. These features are indicated on the geologic hazards maps. Logs washed into major streams from small tributaries during flash floods are a definite hazard to bridges downstream and contribute to flooding of the lowland areas where logjams develop.

Recognition of flooding and stream-bank erosion

The conclusion that stream flooding is a minor hazard in the upland areas is based on a variety of criteria. In a detailed analysis of flooding in the coastal parts of Tillamook and Clatsop Counties, Schlicker and others (1972) demonstrate on a series of hazards maps that regional flooding is essentially a coastal phenomenon restricted to flat-lying areas near sea level. Reconnaissance observations during the floods of January 1972 revealed little bank overflow in the upland areas in spite of the fact that the floods were in the 100-year category (Schlicker and others, 1972). The absence of flooding results in large part from the widespread development of river terraces in the stream valleys. During times of high flow, the rivers are restricted to their channels by the high banks which line them throughout virtually all of the study area.

Although the flatlands in the valleys are free from flooding, the regions in the immediate vicinity of the channels are subject to undercutting and stream-bank erosion, especially during periods of high runoff. The outer banks along channel curves are the most susceptible to this type of hazard because it is there that the momentum of the water carries it against the bank with the most force. Areas of most active stream-bank erosion are recognized by steep slopes, little vegetative cover, and position on the outside of channel curves. Characteristically, slump features are also well developed. Stream-bank erosion is most common along the North Fork of the Nehalem River where terraces consist of unconsolidated alluvium. Elsewhere, as in much of the Trask and Wilson Rivers, bedrock is exposed in the terraced river banks and lateral erosion is much less pronounced.

Flash floods are catastrophic, but generally localized, torrents of water which are largely due to intense periods of rainfall of short duration. Areas of recent flash flooding are easily recognized on the basis of such features as road washouts, scoured channels, and abundant, very coarse debris including logs and boulders heaped along parts of the channels.

Areas of older flash flooding are commonly overgrown and therefore are more difficult to recognize. However, in this study it was noted that channels subject to flash flooding exhibit several features in common. Flash floods tend to occur in regions of steep slope and volcanic terrain. Moreover, the individual streams almost invariably are less than 1 mile in length. It is a general axiom of stream research that the smaller a stream the less orderly is its behavior, and hence the more subject it is to unpredictable behavior and flash flooding. On the basis of the above observations several streams of inferred high potential for flash flooding are indicated on the geologic hazards maps in addition to those streams along which actual flash-flood features have been observed.

Causes of flooding

High stream flow, stream-bank erosion, and flash flooding are favored by a variety of interrelated factors in the study area. The moist climate and sometimes intense rainfall of the winter months and the impermeability of much of the underlying strata combine to give an annual runoff which exceeds 60 inches over most of the study area and which exceeds 100 inches in the upper Wilson River (Phillips, 1969).

Within individual drainage basins a variety of more local factors also influences flooding. In the North Nehalem River basin, gentle slopes, the presence of a relatively wide valley, and the abundance of vegetation favor infiltration and tend to exert a moderating influence on flooding. Along the Trask and Wilson Rivers, however, steep slopes and bare areas resulting from the Tillamook Burn tend to enhance flooding. Moreover, the greater elevations induce greater and more intense rainfall as the moist marine air rises and cools on its way inland. Rapid melting of snow, if present, contributes large quantities of water to the runoff from the rains, but rarely is the chief cause of flooding.

Table 1 presents the major physical and discharge characteristics of the Nehalem, Wilson, and Trask Rivers. Average peak discharges of the Wilson and Trask Rivers (14,000 cfs and 11,000 cfs respectively) indicate a greater runoff per unit area than in the Nehalem River basin. It is evident that relief, slope, vegetative cover, elevation and local climate are significant factors in flooding.

The Nestucca River basin is characterized by elevations, rock types, vegetation, and slopes intermediate between those of the Wilson-Trask area and the North Fork of the Nehalem River. Although pertinent data for that area are lacking, conditions are probably intermediate between the other two areas.

Data from the January floods of 1972 (Table 2) further illustrate the high runoff of the Wilson and Trask drainages per unit area relative to that of the North Fork of the Nehalem River. Although stream-bank erosion along the Wilson and Trask Rivers is minimal and bank overflow is not excessive, the figures are of great importance because they result in large part from flash flooding in the numerous tributaries. The short streams etched in volcanic bedrock and exhibiting steep slopes are especially prone to flash flooding.

Many floods are possible in a single season. An average of slightly greater than two floods per year is recorded for the Wilson, Trask, and Nehalem Rivers by Hulsing and Kallio (1964) for observation periods averaging 20 years in length and ending in 1957. For the Nestucca River a similar average is recorded for the period between 1929 and 1944.

As previously discussed, stream-bank erosion and heavy rains associated with flooding are causative factors in landsliding, and commonly periods of high rainfall are associated with periods of significant mass movement. On several occasions earthflows and mudflows have blocked major streams during periods of high runoff and have brought the threat of catastrophic flooding to the downstream areas. In some cases landslide dams upstream can be detected when streamflow drops abruptly during a storm. Landslide dams present a real hazard if the impounded water is released suddenly.

Log jams in the study area are generally small and are situated along small streams in areas of steep slope. The amounts of water impounded by the jams are negligible and they are not considered to be a flood hazard (Figure 30). Commonly the log jams are quickly bound by brush and boulders and the areas behind them are quickly filled with gravel and sand. In a sense the log jams and log screes tend to retard erosion and are a beneficial feature in the upland areas (Figure 31). In contrast, log jams in the lowland coastal areas are a real flood danger (Schlicker and others, 1972) because they are much larger, they impound great quantities of water, and they are located in regions of low-lying, flat terrain.

Table 1. Drainage basin characteristics*

River	Characteristics					
	Physical		Discharge			
	Area (sq. miles)	Slope ft./mile	Min. (cfs)	Max** (cfs)	Ave. (cfs)	Average peaks 1940-1957
Nehalem	66.7	21	54	43,200	2,704	27,000 (44 floods)
Wilson	159	53	45	32,100	1,210	14,000 (37 floods)
Trask	143	71	37	30,000	964	11,000 (28 floods)

*Adapted from Phillips (1969) and Hulsing and Kallio (1964)
**Excluding floods of January 1972

Table 2. Discharge for 1972 floods*

River	Date			
	January 11, 1972		January 20, 1972	
	Gauge height (ft)	Discharge (cfs)	Gauge height (ft)	Discharge (cfs)
Nehalem	22.6	---	23.0	48,000
Wilson	15.7	32,000	16.9	33,000
Trask	22.0	30,000	18.3	21,400
Nestucca	13.2	22,800	12.2	20,600

* Data provided by Russell Morrow, U.S. Army Corps of Engineers.

Figure 30. One of the many small log jams in the tributary channels of the Wilson River. The volume of water that is impounded behind the dams in regions of steep terrain and narrow canyons is negligible, and the potential for related flood activity is insignificant.

Figure 31. A scree of logs spreading down a side canyon. Accumulations such as this are soon filled with debris and bound with brush; in most instances they retard erosion.

Distribution of Flood Areas

Although high streamflow in the uplands does not result in inundation of the upland valley areas, it is significant in terms of stream-bank erosion, high ground-water table, and flash flooding. Stream-bank erosion is most intense on the outer turns of channels and is indicated on the hazards maps. High water table may buoy or damage buried storage tanks, foundations, and swimming pools. It may also adversely affect drainage from septic tanks. Flash flooding from side channels is a seasonal danger especially in the Wilson and Trask drainages.

Columbia River valley

That part of the Columbia River which borders the project area is totally estuarine and undergoes no significant seasonal fluctuations in depth and areal extent. The small streams draining into the Columbia River are subject to only moderate variations in streamflow and generally pose no threatening hazards to most of man's activities. The Big Creek drainage, however, is subject to torrential flooding and related erosion.

The volcanic terrain, steep slopes, and low permeability of the Big Creek drainage area account in large part for the high runoff. In addition, the high relief of the surrounding mountains may indirectly induce heavy rainfalls.

Torrential flooding of Big Creek is indicated by the large boulders in the stream channel, the abundance of log accumulations, many of which are stranded high above summer water level, and the widespread caving of the stream bank. Commonly trees and even clumps of trees are sent cascading into the creek as the ground beneath them is removed. The meander pattern of the creek (not totally evident on the maps) further contributes to the damage by directing floodwaters against the banks and causing stream-bank erosion.

During the winter floods of 1972 the Big Creek fish hatchery was damaged and farther downstream towards Knappa riprap and dikes were partially destroyed. In addition, fields were partially silted, logs were stranded on farmland, and the formation of gravel bars near Knappa Junction partially blocked the channel of the river.

In the middle and upper reaches of Big Creek, stream-bank erosion is the most significant hazard. Riprapping with stones up to three feet or more in diameter is required to preserve the road from destruction in critical areas (Figure 32). The numerous bridges crossing Big Creek have been constructed of steel piling and concrete. In many instances, however, even this has not been totally adequate because the streams have undermined the approaches.

Nehalem River basin

The major problem associated with flooding in the Nehalem River basin is stream-bank erosion. The terraces are composed of unconsolidated sand and silt, and the main channel follows a sinuous course through the terraced valley. Lateral erosion is characterized mainly by slump and may be a potential threat to highways where abrupt turns in the river are situated very near the roads (secs. 22, 23, 24, T. 6 N., R. 6 W., and sec. 6, T. 5 N., R. 6 W.).

In the middle reaches of the Nehalem River in the vicinity of Elsie, Jewell Junction, and Pope Corner, terrace levels are somewhat lower than in the upper reaches. The additional hazards of localized poor drainage, high ground water, and possible overflow are introduced. More detailed investigation of these factors should be considered prior to development.

South of Jewell Junction the stream gradient is considerably greater than to the north and the tendency to overlow in times of flooding is diminished. The channel is cut in bedrock and stream-bank erosion is minimal. Under such conditions, however, fill placed in the stream is relatively unstable. Consequently, if fill is used in this area, care should be taken to assure that the riprap is large enough to withstand current velocities.

Figure 32. Intense flood activity attacks the stream bank at every turn along Big Creek; here riprop has been placed to protect the road.

Figure 33. Damaged house partially buried in debris brought down Negro Jack Creek (sec. 8, T. 1 S., R. 8 W.) during the floods of 1972. Conditions along the creek conducive to flash flooding include short channel length, steep slopes, and impermeable bedrock.

Wilson River basin

In relation to flooding, the major hazard in the Wilson River drainage basin is flash flooding. During the floods of 1972, torrents from side channels swept over the main highway in dozens of places, causing major damage at several localities. Mudflows are an additional hazard, especially in the lower reaches. The actual channel of the river is scoured in bedrock throughout its entirety and lateral migration under natural conditions is minimal. However, bank erosion in areas of fill constitutes a hazard. In addition, flood waters laden with logs can inflict considerable damage on man-made structures extending into the river.

A mudflow (discussed in section on landslides) blocked the Wilson River in its lower reaches (sec. 18, T. 1 S., R. 9 W.) in 1965, bringing the threat of catastrophic flooding to the lowlands downstream. During times of heavy rainfall and stream flooding the possibility of landslide damming is a danger not only along the Wilson River itself but along most of its major tributaries as well. People residing along major stream channels, therefore, should be aware of the danger and of the signs indicating that upstream damming has taken place (see recommendations). They should be advised that immediate evacuation is imperative when these indications are seen.

The major hazard throughout much of the basin is flash flooding. In the lower reaches of the Wilson River, Deadman Creek, Negro Jack Creek, Smith Creek, Slide Creek, and Fern Creek exhibit potential for flash flooding. Because the primary governing factors, which include steep slope, impermeability, and heavy rainfall, are beyond human control, prevention of flash flooding is not possible. The main means of minimizing damage, therefore, is to avoid placing permanent structures in the downstream sections of these creeks. Had this precaution been followed at an earlier date the recent damage at the mouth of Negro Jack Creek (see Figure 33) would not have occurred.

Directly across the Wilson River from Negro Jack Creek and colinear with it is an unnamed creek with a potential for flash flooding. The surrounding area (NE$\frac{1}{4}$ sec. 17, T. 1 S., R. 9 W.) is designated for future use as a recreation area. If permanent structures are anticipated, they should be placed far enough from the stream to avoid possible damage from flash flooding.

In the upper reaches of the Wilson River, an unnamed stream 2 miles upstream (sec. 4, T. 1 N., R. 6 W.) from McNameras Camp is also subject to flash flooding. It, like most streams subject to flash flooding in the uplands, is characterized by steep slope, impermeable bedrock, and a channel length of one mile or less. During the winter storms of 1972 a logging road crossing the stream washed out, leaving a gulley 20 feet deep and 30 feet across (Figure 34). In light of the information presented in this report such damage was predictable and will probably occur again.

Repairs of the washout included the placing of a small culvert (Figure 35) in the ravine and reconstructing the road. This is common procedure throughout much of the Coast Range of Oregon. In view of the large stream flow, however, large culverts are needed. Proper construction of logging roads at ravine crossings and installation of culverts adequate for maximum flow during flash floods is essential to avoid washouts and also to avoid additional flooding downstream. Culverts should be protected from blockage by logs and debris whenever possible. Improperly designed ravine crossings may function as dams and may break in times of peak flooding. In this way they can cause considerable damage downstream in much the same manner as do landslide dams.

Trask River basin

In terms of flooding the major hazards along the Trask River are landslide damming in the upper reaches and flash flooding of the side channels in the upper and lower reaches. In the valley bottom, terrace levels are fairly high and bedrock is near or at the surface. Danger of appreciable stream-bank erosion in the main channel is minimal. Stream-bank erosion of some of the tributaries and parts of the upper main channel, however, is significant.

Flash flooding due to steep slopes, impermeable bedrock, and intense winter rains is a hazard along many of the short streams in the lower Trask drainage including Cedar Creek (Figure 36), Panther Creek (Figure 37), Burton Creek, and others (Figure 38). In 1972 considerable upstream flash flood damage was done to the main road one mile south of Trask House (Figure 39), where a short unnamed stream washed

Figure 34. Heavy equipment being used to repoir a washed out road along a short tributary of the upper Wilson River (sec. 4, T. 1 N., R. 6 W.). Flash flooding is a common occurrence in the Wilson River droinoge.

Figure 35. Another view of the some washout. From the extent of the damage to the road and along the creek downstream, it is evident that the new culvert will be insufficient to handle the volumes of water that can be expected in future flash floods.

Figure 36. Coarse debris and logs marking the route of the flash flood down Cedar Creek (sec. 30, T. 1 S., R. 8 W.) during the winter storms of 1972.

Figure 37. Debris-strewn channel of Panther Creek, which flash flooded during the winter storms of 1972. Panther Creek is located one-fourth mile from Cedar Creek, which flash flooded during the same storms.

out the road (sec. 6, T. 2 S., R. 7 W.). Structures should not be placed directly in line with streams of high flash flood potential, and roads crossing over them should rest on culverts of adequate size. Likewise, logging roads and other roads higher on the slopes should be designed so as not to restrict the flow of water.

In the upper reaches of the South Fork of the Trask River, terraces are not developed and stream-bank erosion is directed against the hillsides. Where streams twist their way through steep canyons, under-cutting locally is quite pronounced and in places has triggered large-scale mass movement.

In sec. 13, T. 2 S., R. 8 W., a massive earthflow extends from the riverbed upslope for a distance of nearly one mile. Width of the slide is approximately 1,000 feet. As the stream continues to undercut the toe of the slide during future floods, the overall slide mass will continue to migrate slowly downslope. Episodically the slide may block the channel as it did during the January floods of 1972. Under these conditions streamflow is redirected against the west bank of the creek, where it proceeds to undercut and wash out the road.

Similar slides in varying degrees of development are present throughout the upper part of the South Fork of the Trask River drainage. Undercutting of steep slopes at curves in stream channels is instrumental in the formation of many of them. In the slide described above, adequate treatment of the road or relocation may be desirable for several reasons. The slide is located on the main stream, it affects access southward to the Nestucca basin, and it is centrally located within several large plots of land reserved for recreational development. Also it is perhaps the most active slide in the area.

Nestucca River basin

The upper Nestucca River basin is characterized by gentle relief, more vegetative cover, and longer side channels than the more hazardous parts of either the Wilson or the Trask Rivers. The dangers of flash flooding are correspondingly diminished. Terraces are relatively high west of Blaine, and the stream channel is scoured out of bedrock east of Blaine. Stream-bank erosion, although still a hazard, is not extreme. No streamflow data are available for the study area.

Earthquakes

The west coast of North America is situated within an active tectonic belt which encircles the Pacific Basin. Earthquake activity in parts of California is among the most intense in the world, and activity in Washington is moderate. The seismicity of Oregon by comparison is gentle, and earthquake potential in the study area is considered only as a secondary hazard behind flooding and mass wasting.

There is no direct evidence of recent activity along any of the faults inferred in the mapped area. The youngest strata transected by faults are Oligocene in age. The complete seismic record for the north-western United States for the past 10 years shows this part of Oregon to be inactive (National Geophysical and Solar Terrestrial Data Center, Denver, Colorado). However, an earthquake of Intensity IV (Table 3) occurred near Tillamook on February 14, 1939, and an earthquake of Intensity VI was centered near Beaver on November 17, 1957 (Schlicker and others, 1972). Moreover, the youthful canyons and river terraces throughout the mapped area indicate that regional uplift continues.

In regions of moderate to steep slopes and unstable ground conditions (such as much of the project area), earthquake vibrations could initiate significant slope failure. In this regard large earthquakes generated outside the study area are of interest. A total of 47 quakes have been felt in the Portland area since 1841, and one was felt over an area of 20,000 square miles (Schlicker and others, 1972). An earth-quake centered in Olympia, Washington, on April 13, 1949, was felt as far south as Cape Blanco on the southern Oregon coast.

On the geologic maps several faults of local extent are suggested to explain apparent offsets of various rock units. The faults are speculative and should be viewed primarily as tools of the geologist to explain local geology rather than as documentation of recent tectonic activity. There is no evidence to suggest that any of the inferred faults are presently active.

In general, earthquake activity is important to the area only insofar as it may trigger mass wasting in previously unstable areas. Earthquake activity is just one of many factors which may initiate sliding, and it should be regarded as a hazard of secondary importance.

Figure 38. Cluttered channel of a small unnamed tributary (sec. 22, T. 1 S., R. 8 W.) of the Trask River which flash flooded during the winter storms of 1972. The stream exhibits many features conducive to flash flooding.

Figure 39. Washout of the Trask River Highway (sec. 6, T. 2 S., R. 7 W.) caused by the winter storms of 1972. High flow of the Trask River (right of photo) was not a factor. All damage was caused by flash flooding of a small, seemingly insignificant side channel.

Table 3. The Modified Mercalli Intensity Scale of 1931

Scale degree	Effects on persons	Effects on structures	Other effects	Rossi-Forel equivalent	Equivalent shallow magnitude (Richter Scale)
I	Not felt except by few under favorable circumstances			I	
II	Felt by few at rest		Delicately suspended objects swing	I-II	2.5
III	Felt noticeably indoors		Duration estimated	III	
IV	Felt generally indoors		Cars rocked, windows rattled	IV-V	3.5
V	Felt generally	Some plaster falls	Dishes, windows broken, pendulum clocks stop	V-VI	
VI	Felt by all, many frightened	Chimneys, plaster damaged	Furniture moved, objects upset	VI-VII	
VII	Everyone runs outdoors, felt in moving cars	Moderate damage		VIII	5.5
VIII	General alarm	Very destructive and general damage to weak structures Little damage to well-built structures	Monuments, walls down, furniture overturned. Sand and mud ejected. Changes in well-water levels	VIII-IX	6
IX	Panic	Total destruction weak structures, considerable damage well-built structures	Foundations damaged, under-ground pipes broken	IX	
X	Panic	Masonry and frame structures commonly destroyed. Only best buildings survive	Ground badly cracked, rails bent Water slopped over banks		
XI	Panic	Few buildings survive	Broad fissures, fault scarps. Underground pipes out of service	X	8.0
XII	Panic	Total destruction	Acceleration exceeds gravity. Waves seen in ground. Lines of sight and level distorted, objects thrown in air		8.5

MINERAL RESOURCES

Known mineral resources in the uplands area are of minor importance. Quarry rock of variable quality is available locally and is used primarily for local projects. In the river valleys, ground water is available in limited quantities and is used primarily for domestic purposes. With the exception of sparse sand and gravel resources, no other mineral wealth is recognized in the region at the present time.

Quarry Stone

Quarry operations in the uplands are limited in scope and number, and a systematic evaluation of stone reserves in the area has yet to be conducted. The economics of hauling dictate that quarry operations be located within 20 miles of the intended market. Consequently, present operations are aimed primarily at local uses, such as road construction and maintenance. In future years as the need for quarry rock expands in coastal Tillamook and Clatsop Counties, however, quarry rock resources of the uplands may undergo reevaluation.

Intrusive bodies yield the best quarry stone. Generally speaking, it is better suited than stream gravel for use in construction of paved surfaces, macadamized roads, and oil roads. Coarsely jointed intrusive rock is ideally suited for large stone used as riprap. No significant deposits of very coarsely jointed intrusive rock suitable for jetty construction is apparent in the study area.

Flow rocks and breccias form extensive exposures throughout much of the mapped area. Owing to widespread alteration, local deep weathering, and the presence of intercalated sedimentary rock, however, little of it compares in quantity to the intrusive rocks. Consequently it is used only on a very limited basis in logging-road construction.

Columbia River valley

Several active quarry operations are located near the Big Creek Fish Hatchery along the lower reaches of Big Creek in the Svensen quadrangle. Generally the rock consists of basaltic breccia, palagonite (altered glass), and intercalated sedimentary rock and is of poor quality. Much of the stone is used for the maintenance of secondary roads farther up the creek and in the surrounding area. The scattered large blocks that are available are used for riprap along the creek. Because they are composed of breccia they are not suitable for jetty construction. Quarry operations in the lower reaches of Big Creek are hampered by the steepness of the slopes, a factor which leads to rapidly increasing overburden and susceptibility to sliding as the operation advances into the hillside.

Scattered smaller quarries on the upper slopes of Wickiup Mountain (secs. 7, 18, 19, 29, T. 7 N., R. 7 W.) are characterized by low volume, restricted access, and the abundance of associated sedimentary rock. Use is restricted to localized maintenance of nearby access roads. The quarries do not represent a future resource of significant proportions.

The flows of dense subaerial basalt exposed on the east face of Nicolai Ridge are composed of excellent quarry rock. Although interbeds of sandstone and the height of the cliffs introduce the threat of undercutting and sliding, properly engineered procedures such as benching could possibly make this resource accessible in the future. There is no quarrying in the area at the present time. The gentle north slope of Nicolai Ridge in places offers the potential of large-scale operations in basalt by removal of residual soil which is generally less than 10 feet thick.

Nehalem River basin

The Nehalem River basin is one of the most promising regions of the uplands as a large-scale future source of high-quality quarry stone. Widespread dikes of Miocene and Eocene age appear suitable for future development should the economics of hauling become more favorable.

Fresh, medium-jointed dike rock forms an impressive exposure along Sunset Highway immediately east of the North Fork of Quartz Creek (Figure 40). Although no definite record is readily available, it is likely that this deposit has served as a local source of rock for highway construction and maintenance in the past. Farther east additional dikes and intrusive complexes may have potential as future sources of quarry rock.

In the northern Saddle Mountain and Birkenfeld quadrangles numerous colinear dikes of basaltic rock form three northeast-trending ridges at Fishhawk Falls, Flagpole and Boiler Ridges, and near Walker Creek. Several small quarries are scattered throughout the area. Overburden is minimal along many of the ridge crests and rock quality is generally good. With adequate economic incentives these exposures could constitute significant resources if volume is sufficient.

In the central Saddle Mountain quadrangle the Oregon Highway Division intermittently operates quarries along Humbug Creek (secs. 22, 25, T. 5 N., R. 8 W.) and directly south of Humbug Mountain (sec. 17, T. 5 N., R. 8 W.). The rock is of good quality for use as road metal and overburden is not excessive. Significantly, numerous other dikes of similar origin are present nearby, offering the possibility that quarry rock may be plentiful in the area. Immediately south of the highway the dike cluster forming the core of Hill 1794 may form an excellent future source of quarry rock.

Wilson River basin

Intrusive basaltic rock is fairly widespread in the valley walls along the middle reaches of the Wilson River. Individual plutons are limited in size, however, and overburden is a prohibitive factor in many instances. Intrusive rocks are particularly abundant in the hills east of Jordan Creek.

At higher elevations in the middle reaches of the river and at road level in the lower and upper reaches of the river, flow rock and breccias are abundant. Distance to market and local variations in alteration, hardness, and weathering make most of the rock unsuitable for use, however. In places along the upper reaches of the river dense, columnar, subaerial flows may be of future significance.

Trask River basin

Volcanic and intrusive rock form extensive exposures throughout much of the Trask River drainage area and are quarried locally for use as road metal. As in the Wilson River drainage area, the intrusive rock is higher in quality than the flows and breccias. Intrusive basalt is most abundant along the North Fork of the Trask River where it intrudes late Eocene sedimentary rock. In many areas along the South Fork of the Trask River thick overburden and a widespread tendency towards massive ground failure are among the factors which prohibit extensive quarrying.

Nestucca River basin

Volcanic flows and breccias are abundant on the upper slopes of the Nestucca River drainage, and intrusive rock of high quality is available in limited quantities in the lower canyons of the middle reaches of the Nestucca River. Although overburden is frequently a limiting factor, several quarries are in operation immediately upstream from Blaine.

Along the ridge crests near Clarence Creek Road several small basaltic intrusives lie within the predominantly sedimentary terrain. There, small-scale intermittent quarrying serves the local needs for secondary road maintenance and construction (Figure 41).

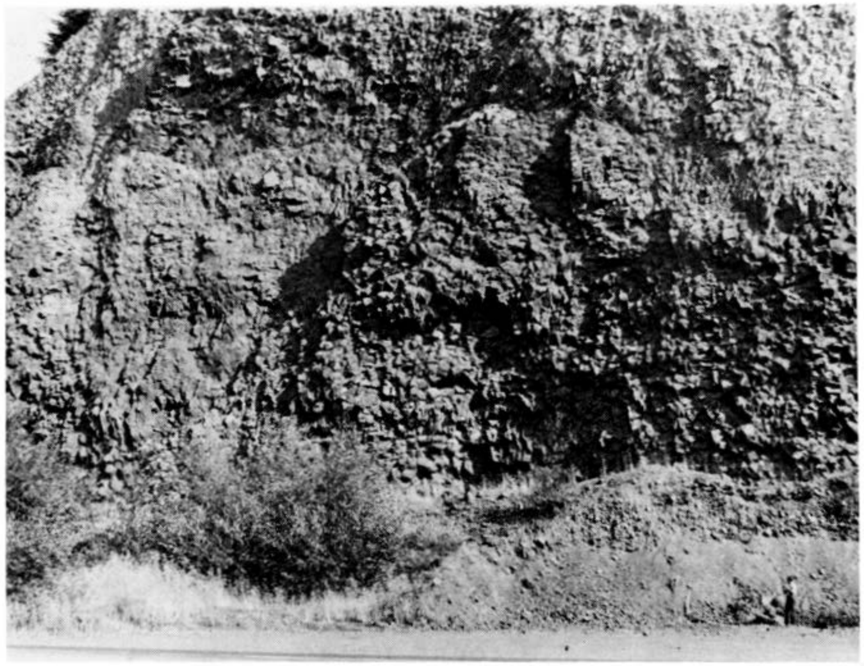


Figure 40. Basaltic dike rock exposed immediately east of the South Fork of Quartz Creek on the Sunset Highway (sec. 11, T. 4 N., R. 4 W.). Although large amounts of rock are available at this and similar dikes, distance to market at the present time is prohibitive.

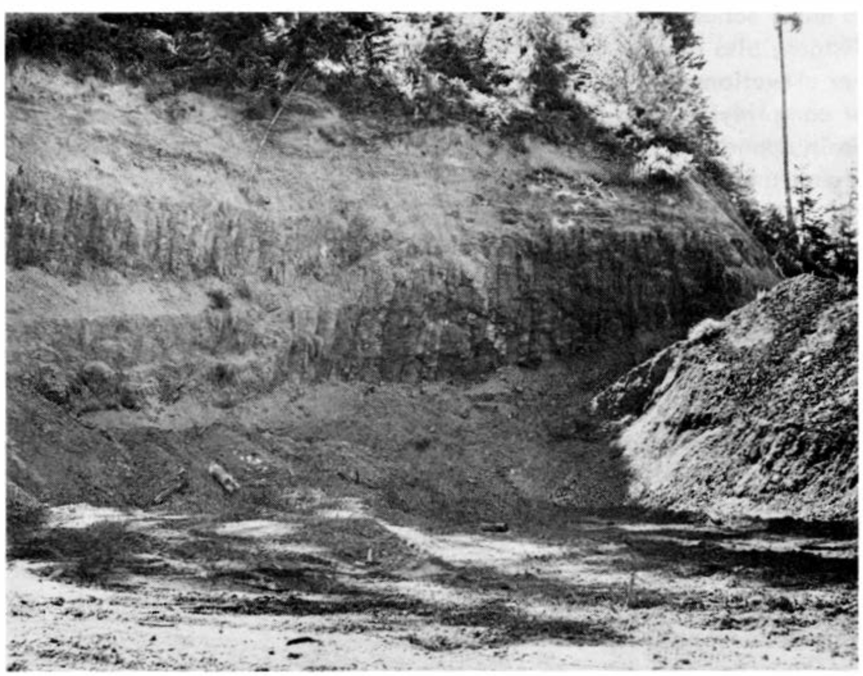


Figure 41. Small quarry in intrusive basalt of medium hardness on the Clarence Creek Road in south-central Blaine quadrangle (sec. 24, T. 3 S., R. 8 W.). Typical of most quarries in the immediate vicinity, this quarry is small and serves only local needs.

Sand and Gravel

Few economic deposits of sand or gravel are recognized along the major streams of the study area. The flood plains are too narrow and the terrace deposits generally are too small or are of the wrong composition. For instance, the terraces along the Nehalem River are composed primarily of silty sand and contain few pebbles. Perched terrace deposits along most of the Wilson and Trask Rivers contain high percentages of pebbles and cobbles locally, but are far too limited in extent to be of economic interest. The flood plains of both the Wilson and the Trask Rivers are too narrow to contain economic quantities af gravel. A small gravel operation is situated in the flood plain of the Trask River immediately west of the study area, however. No gravel deposits are known along the Nestucca River although the wider parts of the flood plain may have some unrecognized potential. Economic deposits of sand or gravel are not recognized along the Columbia River.

In northern Clatsop County the upper Miocene sandstone (Tmus) may have some potential as an economic source of sand. Many exposures are characterized by an abundance of moderately sorted medium-grained sand. At Gnat Creek considerable quantities of sand have been excavated for the production of cement mix.

Ground Water

The study area is characterized by heavy winter rains, dry summers, impermeable bedrock, variable vegetative cover, and gentle to steep slopes. Relatively little water is retained by the ground. Total runoff amounts to approximately three-fourths the annual precipitation and it is concentrated in the winter months.

Bedrock consists of 'tight' volcanic and sedimentary rocks in the Nestucca, Trask, and Wilson River drainages and in the lower Nehalem Basin. Bedrock in the upper Nehalem Basin consists of impermeable clay siltstone and minor sandstone. In the Columbia River valley, bedrock includes impermeable volcanic rock and clay siltstone; also present are large expanses of permeable sandstone and sandstone interbeds in the basalt at lower elevations.

The lack of consolidation and the flat topographic expression of the terrace deposits in the upper Nehalem River Basin apparently favor the storage of ground water and the overall well production there is significantly higher than in the valleys to the south. The ground-water potential of the Columbia River valley area is relatively good in places.

Well data for 37 water wells in inland Tillamook and Clatsop Counties are presented in Table 4. Figure 42 explains the well-numbering system. Although the total number of wells is small and the specific localities of most of them could not be determined, several significant conclusions regarding water production can be drawn.

In the upland areas water wells are basically restricted to valley and canyon bottoms. Because stream flow is so low in the dry summer months and runoff is so abrupt following winter storms, it can be inferred that infiltration on the mountain slopes is minimal and water potential away from the major valleys is very low. Almost all producing wells are drilled in sedimentary rock.

Static water level is 50 feet or less in most wells of the Nehalem River valley and it is 30 feet or less in most of the wells of Tillamook County. Total depth of producing wells is generally less than 200 feet. Water production is erratic even within small areas. In searching for water, therefore, it is advisable to drill several wells of a few hundred feet or less in depth rather than one well with a depth equalling the total depths of the shallower wells.

As shown on the accompanying graphs (Figure 43), most of the producing wells yield approximately 20 gallons per minute in inland Clatsop County and 10 gallons per minute in inland Tillamook County. It is emphasized that these productions are obtained under conditions of low density drilling.

The yield of the Oregon State Game Commission well at Gnat Creek (sec. 24a, T. 8 N., R. 7 W.) in northern Clatsop County is unique in its magnitude (167 gallons per minute). In addition the well was artesian when it was first drilled. Examination of the well log indicates that a thick interbed of permeable sandstone in the impermeable basalt sequence is the producing horizon. Evidently the sandstone interbed crops out farther up the slope where it receives its water. It is possible that other wells drilled in the area would produce considerable quantities of water, if they were drilled deep enough to penetrate the upper flows of basalt and to reach the saturated sandstone interbed.

Future planning for the uplands areas should consider the restrictions and potentials placed by the low ground-water potential of the area as a whole. With the possible exception of the lower north slope of Nicolai Ridge high ground-water production for individual wells should not be anticipated. Reduced yield per well in areas of high density drilling should also be expected.

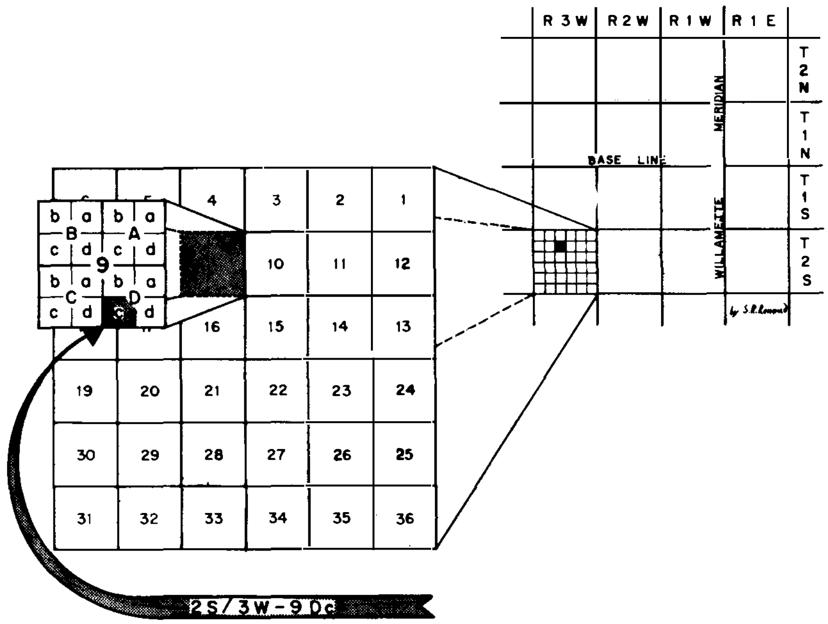


Figure 42. Well-numbering system.

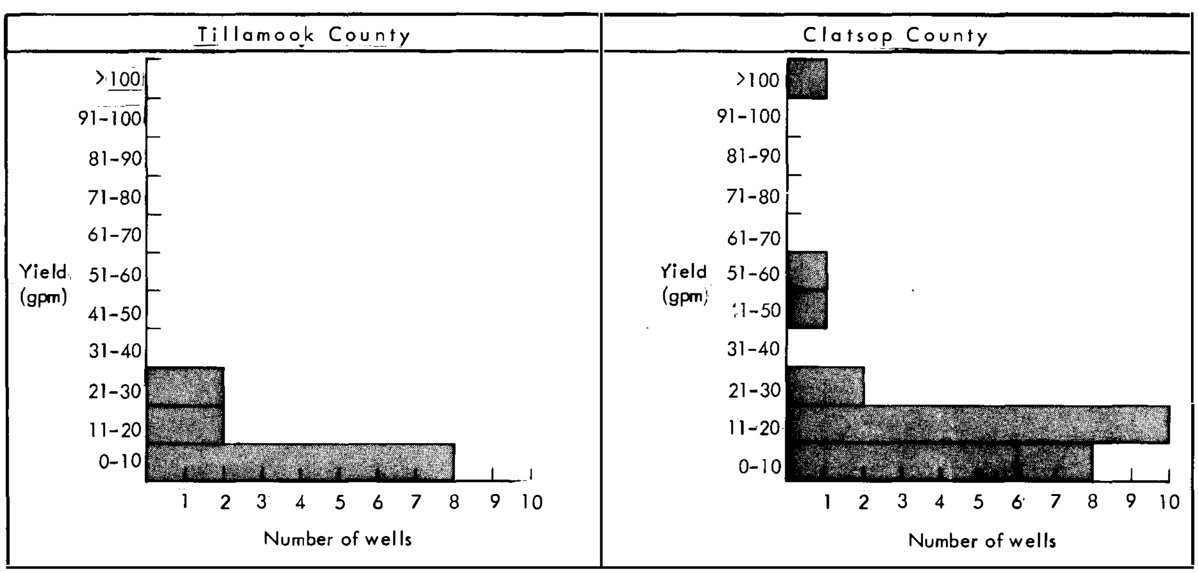


Figure 43. Water-well yield for Tillamook and Clatsop Counties.

Table 4. Water well log data

Location	Owner	Depth	Static water level	Yield (gpm)	Drawdown	Bedrock
			CLATSOP COUNTY			
8 N / 7 W-15	Clark	240	117	3	0	Sed.
8 N / 7 W-16	Flores	185	70	10	3	Sed.
8 N / 7 W-16	Bridgens	78	26	20	20	Sed.
8 N / 7 W-24a	Ore. Game Com.	305	Artesian	167	21	Sed.& basalt
8 N / 7 W-30c	Shafer	95	13	10	87	Sed.
4 N / 7 W-3	Morgan	600	29	9	235	Sed.
4 N / 7 W-4	Prier	70	24	12	46	Sed.
4 N / 7 W-4	Price	60	18	30	20	---
4 N / 7 W-5	Johnson	250	50	2	150	Sed.
4 N / 7 W-6	Mowick	300	4	20	260	Sed.
5 N / 7 W-4Aa	Soderback	61	20	5	20	Sed.
5 N / 7 W-22	Fairchild	165	55	8	75	Sed.
5 N / 7 W-29	Morgan	300	30	30	120	Sed.
5 N / 7 W-21	Hemphill	62	14	12	10	Sed.
5 N / 7 W-29	Morgan	215	50	20	110	Sed.
5 N / 7 W-29	Morgan	200	50	20	115	Sed.
5 N / 8 W-25	Jepson	45	10	15	20	Sed.
5 N / 7 W-28	Hale	125	12	--	--	Sed.
5 N / 7 W-29	Smith	120	15	60	30	Sed.
5 N / 7 W-31	Camberg	255	40	15	182	Sed.
6 N / 6 W-1	Gordon	68	14	15	39	Sed.
7 N / 6 W-1	Bond	195	85	50	25	Sed.
7 N / 7 W-4	Svehag	70	--	--	--	Sed.
7 N / 7 W-4	Svehag	49	16	20	4	Sed.
			TILLAMOOK COUNTY			
1 N / 7 W-30	Bachelor Club	65	30	8	5	Sed.
1 N / 7 W-9Bb	Forest Service	110	2	22	30	Sed.
1 N / 7 W-30	Crass	215	10	2	190	Sed.
2 N / 7 W-2Ab	Erickson	85	24	10	49	Sed.
1 S / 7 W-7	-------	48	21	20	19	Sed.
2 S / 8 W-1	Philips	145	16	15	35	Sed.
2 S / 8 W-1	Pendergrass	200	18	5	60	Basalt & Sed.
3 S / 7 W-27	BLM	250	21	2	229	Basalt
3 S / 7 W-27Bd	BLM	206	21	30	83	Basalt
3 S / 8 W-30	Harris	205	20	--	--	Sed.
4 S / 8 W-2	King	65	34	10	14	Sed.
4 S / 8 W-3	Herr	90	16	1	--	---
4 S / 8 W-3	Herr	40	12	7	28	---

SUMMARY

The parts of the basins of the Nehalem, Wilson, Trask, and Nestucca Rivers investigated in this study are subject to a variety of geologic hazards of interest to the planner. Conditions leading to instability vary in relative importance from place to place and include rock type, slope, climate, drainage, vegetative cover, and numerous other factors. Information presented in this report may lead to revisions and additions to zoning regulations and building codes and should serve as reference material for numerous other county functions involving land use.

Areas of steep slope are susceptible to rockslide, rockfall, rapid earthflow, and slump; slope angles are therefore indicated on the geologic hazards maps. Gentle slopes are generally more stable, although "mass movement topography" (indicated on the geologic hazards maps) reveals previous unstable behavior over large areas. Oversteepening, improper drainage control, and other activities could easily reactivate sliding in many of these places. Finally, areas of apparent stability, in which slopes are not steep and mass movement features are not recognized, may in fact possess a capacity for unstable behavior. Reference to the geologic maps and the text may provide general information on these potential problems.

By contrast to the coastal region, flooding of the Nehalem, Wilson, Trask, and Nestucca Rivers inland is a minimal hazard in the study area because of the well-developed terraces in most of the valleys. In addition, storm tides which generally accentuate lowland flooding along the coast are not a factor inland. The major dangers associated with running water include stream-bank erosion along the major streams and flash flooding in many of the tributaries. These processes also are indicated on the geologic hazards maps.

It is emphasized that this study points out the general geologic hazards arising from natural conditions as they exist at the present time. The purpose of the study is to provide some of the basic information needed to assure that future developments are as intelligently keyed to the geologic conditions as possible.

Columbia River Valley

The Columbia River Valley area is underlain by many different rock units, each with its own particular set of stability characteristics. In the uplands Miocene volcanic rock forms gentle slopes with a clayey soil cover of varying thickness and steep slopes susceptible to rockslide. Oligocene to Miocene sedimentary rocks in the middle and upper reaches of Big Creek are undergoing a variety of mass wasting processes. The terrain is very unstable and this, in conjunction with the additional hazard of flooding, makes most of this area unsuitable for intensive development.

The lowlands are underlain by Oligocene to Miocene siltstone, upper Miocene sandstone, and Quaternary alluvium. The siltstone terrain near Wauna is disrupted to great depths by ancient landslides; the associated alluvium is high in organic content owing to marshland development at the toe of the slide as it impinged upon the Columbia River. The upper Miocene sandstone exhibits shallow failures, especially in the northern extremities. The Quaternary alluvium of the Svensen quadrangle is saturated with water and is high in organic content; it is probably best suited for agricultural purposes.

Nehalem River Basin

The Nehalem River drainage area is underlain by volcanic rocks in the lower reaches and by clayey siltstones and scattered intrusions and volcanic rocks in the upper reaches. Flat-lying, unconsolidated terrace material lines the major streams. Geologic hazards include rockslide in the volcanic terrain, earthflow and a variety of related mass wasting processes in the sedimentary rock terrain, and stream-bank erosion along the Nehalem River.

Much of the sedimentary rock terrain in the northern Nehalem River basin is unstable to semi-stable and is marked by a subdued topographic expression characteristic of shallow mass wasting. Earthflow, slump, and soil creep are widespread in many areas. Elsewhere, modifications by man such as undercutting, overloading, removal of vegetation, and drainage readjustments may initiate future sliding. Generally speaking, ridge slopes are the least stable, and ridge crests and areas around large intrusions are the most stable. Depths of failure usually do not exceed a few tens of feet. Future planning for dams, road construction, housing developments and other projects must consider present instability conditions, the potential for future sliding, and the low permeability of the strata. Closely spaced septic tanks and drain fields are not recommended in the Oligocene-Miocene sedimentary rock unit in areas of moderate to steep slope.

Flat-lying terrace areas along the major streams are locally subject to ponding, high water table, and stream-bank erosion during the winter months. Projects involving subsurface development such as basements, swimming pools, and buried storage tanks for fuel and other materials must consider the possibilities of buoying or flooding. Areas of active stream-bank erosion should be stabilized prior to development.

Wilson River Basin

The Wilson River drainage area is underlain by impermeable volcanic rock in the lower reaches; volcanic, intrusive, and sedimentary rock in the middle reaches; and sedimentary rock and crumbly to hard volcanic rock in the upper reaches. Geologic hazards include earthflow, rockfall, mudflow, and flash flooding.

The mudflow of 1965, located 8 miles east of Tillamook, left a large hillside scar which warrants observation or possible corrective action. Because mudflows tend to be recurrent in the same channel, development of vegetative cover or drainage adjustments may be required to insure against future activity.

The possibility of landslide dams blocking stream channels and causing catastrophic flooding downstream is a very real danger in the Wilson River drainage. Residents in the basin and in the coastal lowlands downstream should be informed that sudden decreases of stream discharge during storms and times of expected high stream flow may signal development of a landslide dam upstream. Under these conditions evacuation is imperative. Methods of dealing with landslide dams once they have developed also should be formulated.

Flash flooding of stream channels in the middle and lower Wilson River drainage is a major geologic hazard. Because the factors of rainfall, basin geometry, slope, and bedrock permeability are beyond practical human control, zoning regulations are perhaps the most realistic means of minimizing losses. Also, plans for road construction and repairs across streams subject to flash flooding should require culverts large enough to handle the maximum predictable runoff. Log jams are not a serious hazard in the Wilson River drainage.

In all areas undercutting should be avoided and modifications of drainage, vegetation and slope angle should be made only after due consideration has been made of the potential for sliding. Dangers due to rockfall can be minimized by screening steep slopes or by periodically scraping away loose debris with a bucket scraper. Ridge crests and areas around large intrusions are the most stable, and attempts should be made to locate necessary roads along these features. Closely spaced septic tanks and drain fields are not recommended in the steep bedrock areas; they should be placed in the valleys away from the edges of the terrace material.

Trask River Basin

The Trask River drainage area is underlain by impermeable volcanic bedrock in the lower reaches and interbedded volcanic and sedimentary rock in the upper reaches. Major geologic hazards include flash flooding and earthflow. As with the Wilson River, flash flooding cannot be corrected in a practical way and should be dealt with in terms of zoning regulations. Proper design should be required for those constructions, such as roads, which must cross streams subject to flash flooding.

Projects which affect slope, vegetation, drainage, and moisture content of the soil must consider the inherent instability of moderate to steep slopes. Undercutting, removal of vegetation, close spacing of septic tanks and urbanization may initiate sliding in certain areas. Permeability studies should be required before septic tanks are placed in bedrock areas.

An earthflow located one mile south of Hollywood Camp on the South Fork of the Trask River illustrates many of the problems associated with such ground movement and may warrant radical corrective action in future years. A road built into the river on the west bank deflects floodwaters against the earthflow on the east bank during times of flooding. Episodically undercutting initiates sliding, which in turn blocks the channel and causes the road to wash out. At the present time close observation is recommended to see if recent repairs of the road are sufficient to withstand the effects of future floods.

Nestucca River Basin

The Nestucca River drainage area is underlain by sedimentary rock and minor intrusive rock along most of the lower slopes and by volcanic rock in the narrow canyon immediately upstream from Blaine. Major geologic hazards include localized rockfall along the steeper slopes and earthflow in the sedimentary rock terrain. Flash flooding does not appear to be as significant as in the Wilson and Trask River drainages. In this river basin, as in the others, a knowledge of the potential for mass movement should be incorporated into the planning processes. Activities which may effect such stability factors as slope, vegetative cover, drainage, and moisture content of the soil should be regulated.

RECOMMENDATIONS

1. Steep slopes are at or near natural equilibrium and further steepening could initiate sliding. Excavations in these areas should be restricted and should be properly engineered.

2. Excavations in areas of mass-movement topography should be restricted and should be supervised and deemed safe by the appropriate county personnel or by personnel approved by the county.

3. Excavations in sedimentary rock terrain (Tesu, Toms, Tmms, Tmus) should be properly engineered to assure against slope failure.

4. Where strata slope toward cuts, slides are easily initiated; excavations in areas with such unfavorable bedrock conditions should be properly engineered.

5. The county should develop grading codes consisting of standards for excavations, fill, and drainage for each rock unit to minimize sliding during and after development.

6. Adequate engineering studies should be required for all moderate to large structures, especially those planned for sedimentary rock terrain.

7. Projects involving modifications of established drainage patterns should be evaluated in terms of potential for altering land stability.

8. Projects which include plans for modifying the topography of sloping areas should be evaluated in terms of the effect these changes would have on drainage and slope stability.

9. Projects or long-range plans involving urbanization of given areas should be evaluated in terms of the long-range influence the proposed land use would have on land stability; drainage is particularly critical.

10. Because of the potential for ground- and surface-water contamination, septic tanks should not be placed in most bedrock areas; suitability at particular sites should be demonstrated by adequate investigations.

11. Closely spaced drain fields and septic tanks should be restricted from moderate to steeply sloping areas because of the potential for sliding.

12. Roads crossing channels subject to flash flooding should be founded on culverts of adequate size to handle maximum runoff.

13. Permanent structures should not be placed in channels subject to flash flooding.

14. The public should be informed by the appropriate agency that an abrupt drop of stream flow during times of flooding may signal the development of a landslide dam upstream. Evacuation procedures for downstream residents should be formulated in the event of such an emergency.

15. Mudflows are particularly damaging and tend to recur in the same channel; permanent structures should not be permitted in the paths of past mudflows.

16. The mudflow 8 miles east of Tillamook should be studied in greater detail to determine the potential for future activity; a landslide dam at this point in the Tillamook River could threaten valley areas downstream with flash flooding.

17. Records of maintenance costs should be kept for the road affected by the massive earthflow in the upper reaches of the Trask River (sec. 13, T. 2 S., R. 8 W.); rerouting in the future may be more economical.

18. Future planning for the uplands should consider the restrictions inherent in the low ground-water potential of the area. Well productions average 10-20 gallons per minute under conditions of low-density drilling.

19. In drilling for water, a few moderate-depth wells (200 feet) are more likely to produce water than one deep well.

20. Buoyant structures such as basements, buried gas tanks, and swimming pools should not be permitted in areas of high ground-water table.

21. Future evaluation of damsites should consider the possibility of landslide activity initiated by the fluctuating water level in the entire reservoir area.

22. Construction in the river terrace and alluvial areas should avoid sites subject to flooding or ponding of rainwater.

23. Construction in the alluvial areas should avoid areas of peat or should be properly engineered to prevent damage from possible differential settling.

24. Ridge crests are the least susceptible to sliding or washouts; secondary roads should follow ridge crests where possible.

25. Flood currents are particularly strong in channels scoured in volcanic bedrock; placing of artificial fill in these areas generally should not be permitted.

26. Bridges built over channels scoured in bedrock should be capable of withstanding tremendous current velocities.

27. The Oligocene to Miocene sedimentary rock unit is unsuitable for fill and generally should not be used for that purpose.

GLOSSARY

Alluvial: Descriptive term applied to clay, silt, sand, and gravel that has been transported and deposited by river action.

Amygdaloidal: Descriptive term applied to flow rock in which the air bubbles are filled with secondary mineral matter such as opal.

Anticline: An upfold or arch of layered rock in which beds dip away from the axis on either side of the structure.

Arkose: Sandstone composed primarily of grains of quartz and feldspar and having very little intervening matrix.

Aphanitic: An igneous rock composed of crystals too small to be seen with the unaided eye.

Attitude: A measure in degrees of the amount and direction of dip or tilt of a planar body such as a layer of sedimentary rock.

Basalt: A dark, fine-grained volcanic rock composed primarily of calcic plagioclase and pyroxene; occurs in flows, dikes and sills.

Breccia: A rock unit made up of coarse angular fragments.

Conformable: Relationship of sedimentary rocks oriented parallel to one another and interpreted to have been deposited continuously without any significant break in deposition.

Conglomerate: Sedimentary rock composed primarily of pebbles greater than 2 millimeters in diameter.

Consolidated: Loose earth material that has become firm through compression or cementation.

Creep: Slow particle-by-particle downslope movement of soil under the influence of gravity and assisted by a variety of chemical, physical and organic processes.

Dike: A tabular intrusive body of igneous rock that cuts across the bedding or structure of the adjacent rocks.

Dip: The angle of inclination of a tilted bed with a horizontal plane of reference.

Earthflow: The downslope movement of unconsolidated earth or fragmented rock debris in a manner which resembles the flow of a highly viscous fluid.

Erosion: The removal and transport of earth material by a variety of mass-wasting processes and moving water.

Facies change: Subtle lateral variations in rock type within a recognized stratigraphic unit.

Fall: A class of mass movement which involves free fall of rock or earth material or rapid sliding down steep slopes.

Fault: A fracture in rock along which displacement has occurred.

Flash flood: Abrupt rise in stream flow arising from storm activity and causing bank overflow. In the study area flash flooding is most common along short side channels to major streams.

Flow: A layer of volcanic rock that was originally a lava flow. Also a class of mass movement of soil and rock materials along innumerable shifting and transient shear planes; overall movement resembles that of a highly viscous fluid.

Friable: Descriptive term applied to sandstone that is easily crumbled.

Gabbro: A coarse-grained igneous rock that cooled beneath the earth's surface and which is compositionally similar to basalt.

Head (of a slope): The upslope boundary of a mass of slide material.

Igneous: Rocks formed by the cooling and solidification of molten magma, such as basalt and gabbro.

Indurated: Converted into rock by heat, pressure, or cementation.

Intensity: A subjective measure of the strength of an earthquake based on its visible effects on the works of man at a particular locality. In addition to the amount of energy released, intensity is influenced by local geology and the nature of man-made structures.

Intrusion: A body of igneous rock implaced beneath the surface of the earth.

Jointing: The presence of fractures.

Landslide: Perceptible downslope movement of earth material on moderate to steep slopes.

Lapilli: A descriptive term denoting volcanic tuffs composed of angular fragments varying in size from 4 millimeters to 32 millimeters.

Lateral equivalence: Two distinct stratigraphic units known to be of the same age are said to be lateral equivalents.

Lithic: Descriptive term applied to sedimentary rocks the individual grains of which are composed of volcanic or metamorphic rock.

Lithologic: A loosely used term which pertains to rock composition and texture.

Littoral: Descriptive term referring to the zone between high and low tides.

Magnitude: An objective measure derived through use of precise instruments of the actual amount of energy released by an earthquake.

Massive: Descriptive term applied to deposits which are very thick bedded and which lack structure on a smaller scale.

Mass wasting: Downslope movement of earth material under the influence of gravity without the aid of running water.

Megafossil: Fossil visible without magnification; includes clams and snails.

Micaceous: Containing visible abundances of mica.

Microfossil: Fossils visible only with the use of magnifying equipment; includes foraminifers and radiolarians.

Mudflow: Rapid downslope movement of a mudlike slurry of earth material.

Palagonite: Varicolored hydrated basaltic glass common in basalts extruded under water. Frequently black but weathers to bright yellow.

Phaneritic: Term applied to igneous rocks in which the individual grains are visible without magnification.

Pillow lava: Flows of volcanic rock that are made up largely of rounded bodies of lava which ideally exhibit radial jointing as a result of cooling. Pillow structures are indicative of extrusion of lava under water.

Porphyritic: A textural term applied to igneous rocks which consist of relatively large crystals in a finer grained matrix.

Pyroclastic: Descriptive term applied to volcanic rocks derived from explosive volcanic eruptions.

Radiolarian: A family of siliceous microfossils indicative of open sea conditions during the deposition of the rocks in which they occur.

Rockfall: Type of mass wasting in which pieces of rock fall vertically or cascade rapidly down steep slopes.

Rockslide: Perceptible downslope movement of rocky material down moderate to steep slopes.

Sandstone: Sedimentary rock composed primarily of grains between 1/16 millimeter and 2 millimeters in diameter.

Scoriaceous: Descriptive term applied to volcanic rock in which the abundance of gas pockets results in a frothy appearance.

Sedimentary rock: Rock formed by the deposition of individual grains from a transporting medium, as opposed to igneous and metamorphic rocks.

Seismicity: Pertaining to earthquakes.

Shear plane: Planar surface along which rock movement or shearing has occurred.

Sill: A tabular body of igneous rock that is oriented parallel to the bedding of the surrounding rocks.

Siltstone: Sedimentary rock primarily composed of grains less than 1/16 millimeter in diameter, but larger than clay.

Slide: An area that has undergone mass movement.

Slump: A downward movement of earth material in response to gravity characterized by backward rotation of the moving material and by movement along a curved basal-slip plane.

Spheroidal weathering: Weathering of massive rocks which produces closely packed rounded boulders.

Stratum: A depositional layer of rock. Plural is strata.

Stratigraphic: Pertaining to the relative position or age of layered rocks.

Strike: Trend of a bed measured on a horizontal surface.

Stream-bank erosion: Caving and removal of stream banks by streamflow.

Subaerial: Formed, existing, or taking place on the earth's surface, as opposed to under water.

Submarine: Refers to rocks deposited under the sea.

Talus: Uniformly sloping deposit of rock debris at the foot of a steep cliff, formed by rockfall and rock slide.

Tectonic: Pertaining to the process of mountain building. Folding, faulting, and uplift are among the processes generally referred to as tectonic.

Terrace: A relatively flat-lying elevated surface of former deposition.

Texture: Refers to those aspects of a rock that can be described in geometric terms, including the size, shape, and distribution of the constituent grains or crystals.

Toe of a slide: The lower extremity of a mass of earth that has undergone downslope movement.

Tuff: A rock formed of small pyroclastic fragments of volcanic material such as pumice.

Turbidite: A stratigraphic unit consisting of thin lateral persistent beds of sand deposited by turbidity currents.

Unconformity: A surface of erosion separating two sequences of strata. The upper sequence is said to be unconformable over the lower one, and a period of erosion is inferred to have occurred between the deposition of the two sequences.

Vesicular: Pertains to volcanic flow rock which contains scattered gas bubbles.

Volcanic: Pertains to rock formed by the extrusion of igneous material on the earth's surface.

Volcaniclastic: Pertains to sandstones and conglomerates eroded from a volcanic terrain and deposited in adjacent areas.

Weathering: A collective term referring to any or all of the natural physical, chemical, and organic processes through which rock is broken down to form unconsolidated material.

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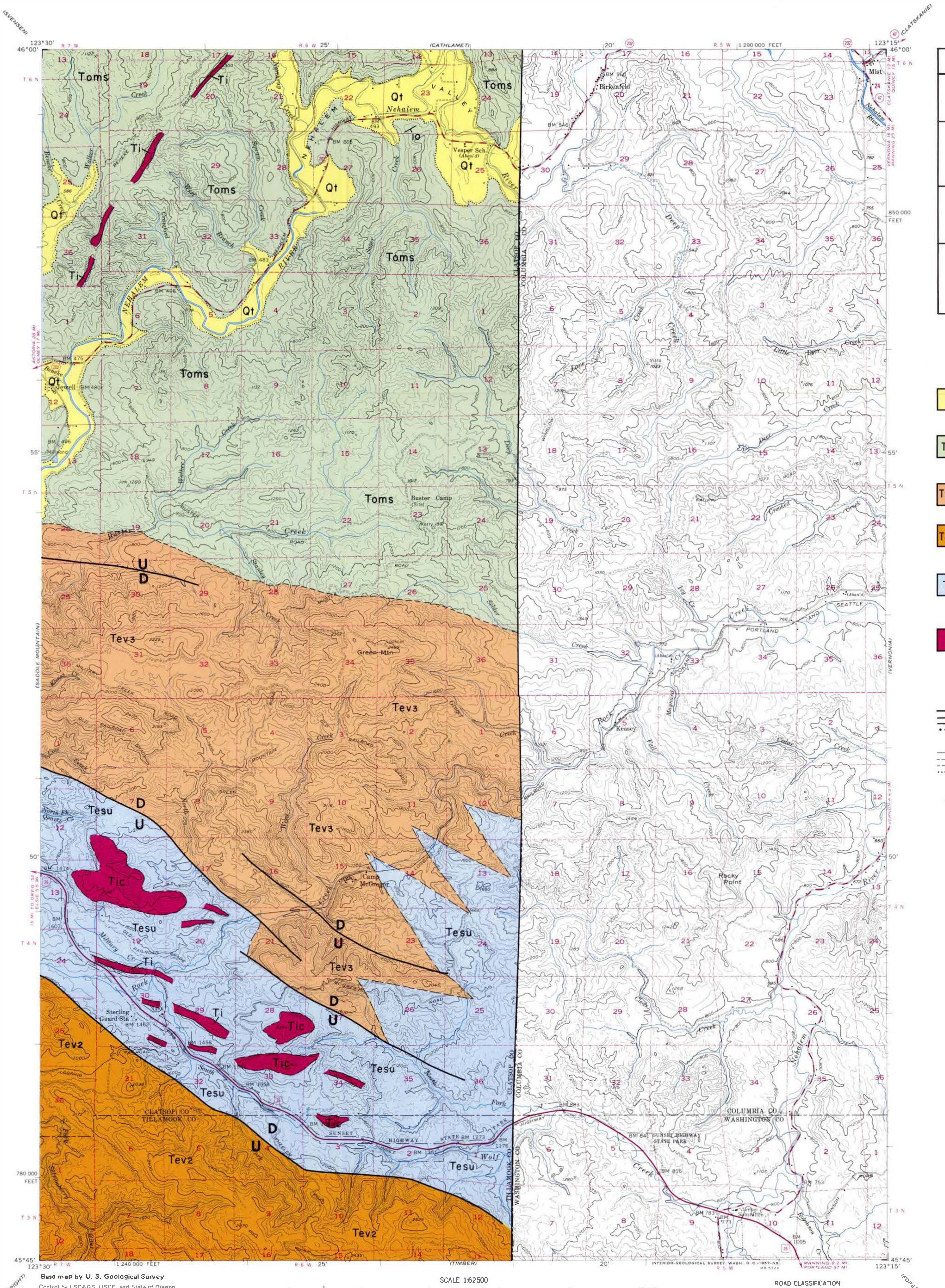
GEOLOGIC MAP
of the
BIRKENFELD QUADRANGLE
OREGON



Base map by U. S. Geological Survey
Control by USC&GS, USCE, and State of Oregon
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Field check 1955
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
Dashed land lines indicate approximate locations

SCALE 1:62500
1 ½ 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

TRUE NORTH
MAGNETIC NORTH
22°
APPROXIMATE MEAN DECLINATION, 1955

OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty .... Light-duty ....
Medium-duty .... Unimproved dirt ....
U. S. Route   State Route

STRATIGRAPHIC TIME CHART

Pleistocene		Qt		
Pliocene				
Miocene	L	Tmus		Ti/Tic
	M	Tmv		
	E	Tmms		
Oligocene		Toms		
Eocene	L	Tev 3, Tev 2	Tesu	Ti/Tic
	M	Tev I		
	E			

EXPLANATION

Unconsolidated Surficial Units

Qt — Quaternary Terrace Deposits
Dissected alluvium consisting primarily of poorly sorted silt, sand, and gravel.

Stratigraphic Units

Toms — Oligocene to Miocene Sedimentary Rock
Greater than 5,000 feet of massive- to thin-bedded, medium- to dark-gray, tuffaceous siltstone with subordinate amounts of sandstone locally. Includes Astoria age strata at the base of Saddle Mountain and Humbug Mountain.

Tev 3 — Eocene Volcanic Rock, Unit-3
Several thousand feet of relatively flat-lying basaltic flow rock and pillow basalts of marine and subaerial origin intercalated with subordinate amounts of shallow-water volcaniclastic sedimentary rock.

Tev 2 — Eocene Volcanic Rock, Unit-2
At least 15,000 feet of basaltic breccia (Enright and Blaine quadrangles), submarine basaltic flow rock (Saddle Mountain quadrangle), and subaerial flow-on-flow basalt (Timber quadrangle) intercalated with subordinate amounts of tuffaceous, thin-bedded siltstone.

Tesu — Eocene Sedimentary Rock Undifferentiated
Several thousand feet of undifferentiated, thin-bedded to indistinctly bedded, tuffaceous, volcaniclastic siltstone, clay siltstone, and sandstone. The sedimentary rock occurs stratigraphically between the three Eocene volcanic units and grades laterally into them locally. Volcanic interbeds are present in places.

Ti — Intrusive Rock
Basaltic intrusive rock of late Eocene and middle Miocene age including dikes and sills (Ti) and complex associations of intrusive rock and sedimentary rock (Tic). The Miocene intrusions are restricted to post-Eocene terrain and are characterized by a dense, uniformly grained texture. Eocene intrusions commonly contain indistinct phenocrysts of pyroxene.

Geologic Symbols

Faults
Solid where definite; long dashes where approximately located or indefinite; short dashes where inferred; and dotted where concealed. U, upthrown side; D, downthrown side.

Contacts
Solid where definite; long dashes where approximate; short dashes where inferred; and dotted where concealed.

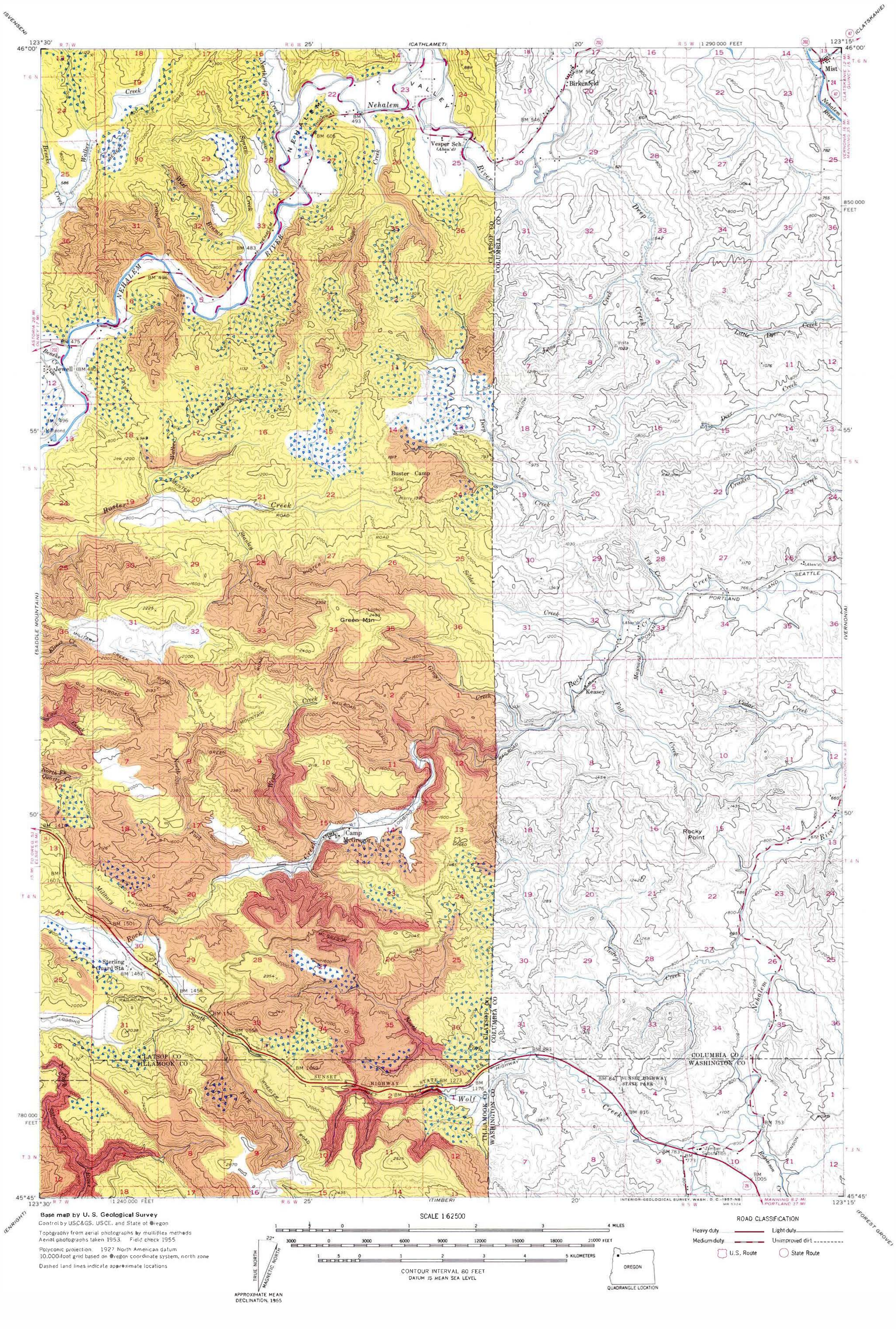
⊕ Horizontal Beds
⊥ Strike and dip of beds or flows
⚒ Rock quarries

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

HAZARD MAP
of the
BIRKENFELD QUADRANGLE
OREGON



EXPLANATION

0 - 9% Slope

10 - 24% Slope

25 - 49% Slope

>50% Slope

(Increasing danger of mass movement with increasing slope)

Mass Movement Topography

Mudflow

Potential for Flash Flood

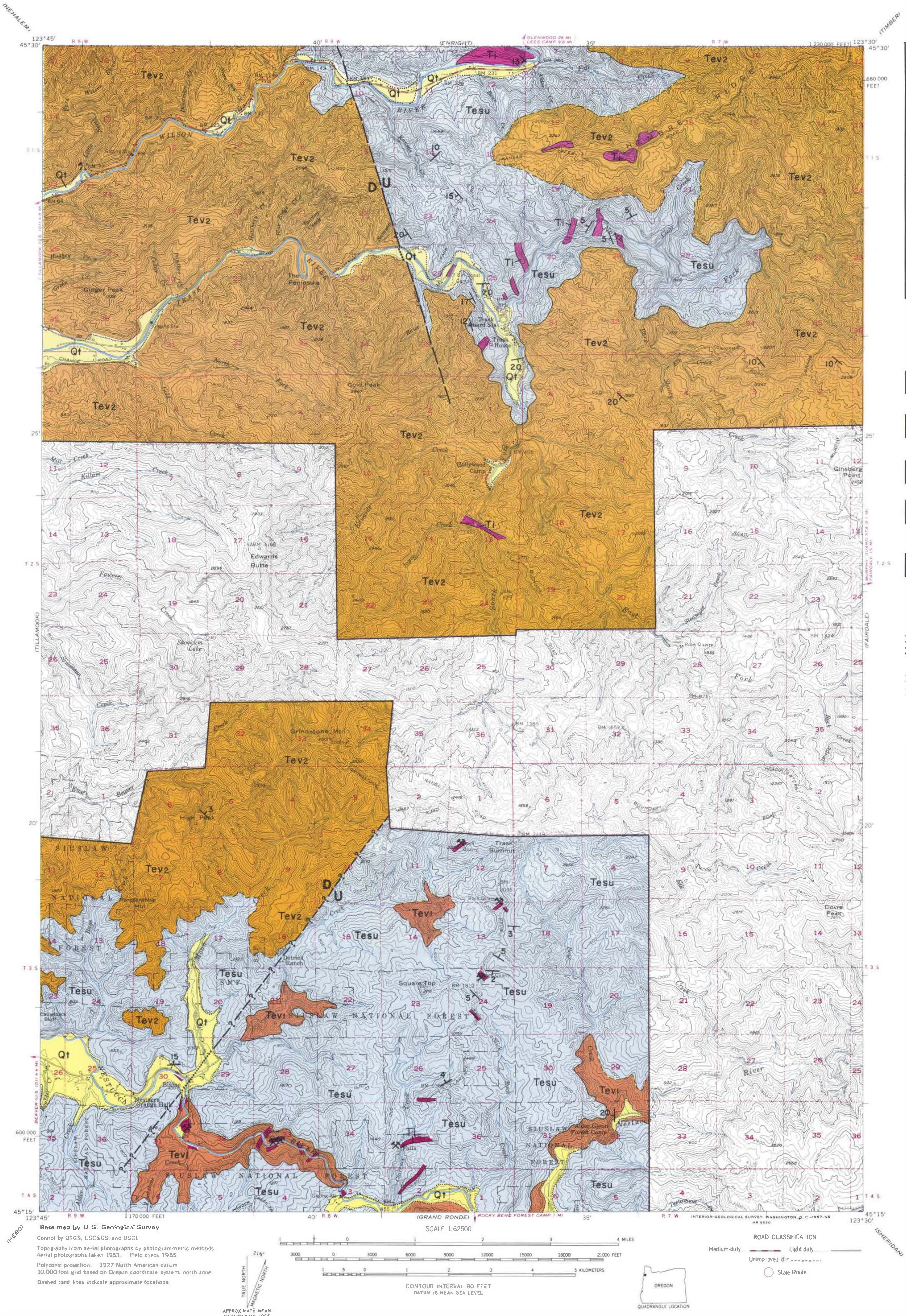
Stream Bank Erosion

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

GEOLOGIC MAP
of the
BLAINE QUADRANGLE
OREGON



STRATIGRAPHIC TIME CHART

Plei.		Qt		
Pliocene				
Miocene	L	Tmus		Ti/Tic
	M	Tmv		
	E	Tmms		
Oligocene		Toms		
Eocene	L	Tev 3, Tev 2	Tesu	Ti/Tic
	M	Tev 1		
	E			

EXPLANATION

Unconsolidated Surficial Units

Qt — Quaternary Terrace Deposits
Dissected alluvium consisting primarily of poorly sorted silt, sand, and gravel.

Stratigraphic Units

Tev 2 — Eocene Volcanic Rock, Unit-2
At least 15,000 feet of basaltic breccia (Enright and Blaine quadrangles), submarine basaltic flow rock (Saddle Mountain quadrangle), and subaerial flow-on-flow basalt (Timber quadrangle) intercalated with subordinate amounts of tuffaceous, thin-bedded siltstone.

Tev 1 — Eocene Volcanic Rock, Unit-1
Approximately 1,000 feet of pillow basalt and zeolite-cemented basaltic breccia intercalated with bedded siltstone in the valley bottoms of the Nestucca River drainage.

Tesu — Eocene Sedimentary Rock Undifferentiated
Several thousand feet of undifferentiated, thin-bedded to indistinctly bedded, tuffaceous, volcaniclastic siltstone, clay siltstone, and sandstone. The sedimentary rock occurs stratigraphically between the three Eocene volcanic units and grades laterally into them locally. Volcanic interbeds are present in places.

Ti — Intrusive Rock
Basaltic intrusive rock of late Eocene and middle Miocene age including dikes and sills (Ti) and complex associations of intrusive rock and sedimentary rock (Tic). The Miocene intrusions are restricted to post-Eocene terrain and are characterized by a dense, uniformly grained texture. Eocene intrusions commonly contain indistinct phenocrysts of pyroxene.

Geologic Symbols

Faults
Solid where definite; long dashes where approximately located or indefinite; short dashes where inferred; and dotted where concealed. U, upthrown side; D, downthrown side.

Contacts
Solid where definite; long dashes where approximate; short dashes where inferred; and dotted where concealed.

⊕ Horizontal Beds
⊥ Strike and dip of beds or flows
⚒ Rock quarries

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
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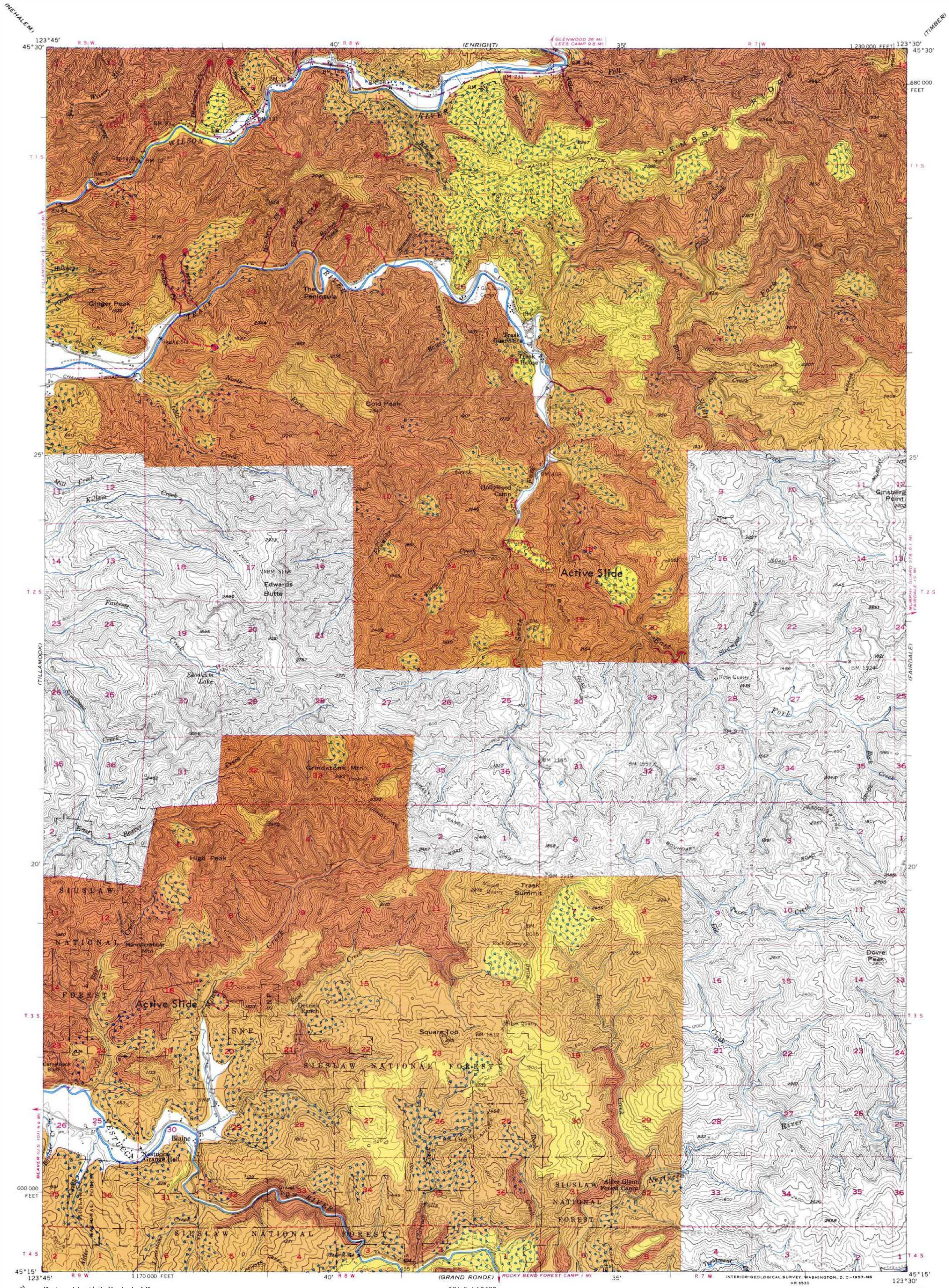
R. E. CORCORAN, STATE GEOLOGIST

HAZARD MAP
of the
BLAINE QUADRANGLE
OREGON



EXPLANATION

0 - 9% Slope

10 - 24% Slope

25 - 49% Slope

>50% Slope

(Increasing danger of mass movement with increasing slope)

Mass Movement Topography

Mudflow

Potential for Flash Flood

Stream Bank Erosion

Base map by U.S. Geological Survey
Control by USGS, USC&GS, and USCE
Topography from aerial photographs by photogrammetric methods
Aerial photographs taken 1953. Field check 1955
Polyconic projection. 1927 North American datum
10,000 foot grid based on Oregon coordinate system, north zone
Dashed land lines indicate approximate locations

APPROXIMATE MEAN DECLINATION, 1955

SCALE 1:62 500

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Medium-duty Light-duty
Unimproved dirt
State Route

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
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R. E. CORCORAN, STATE GEOLOGIST

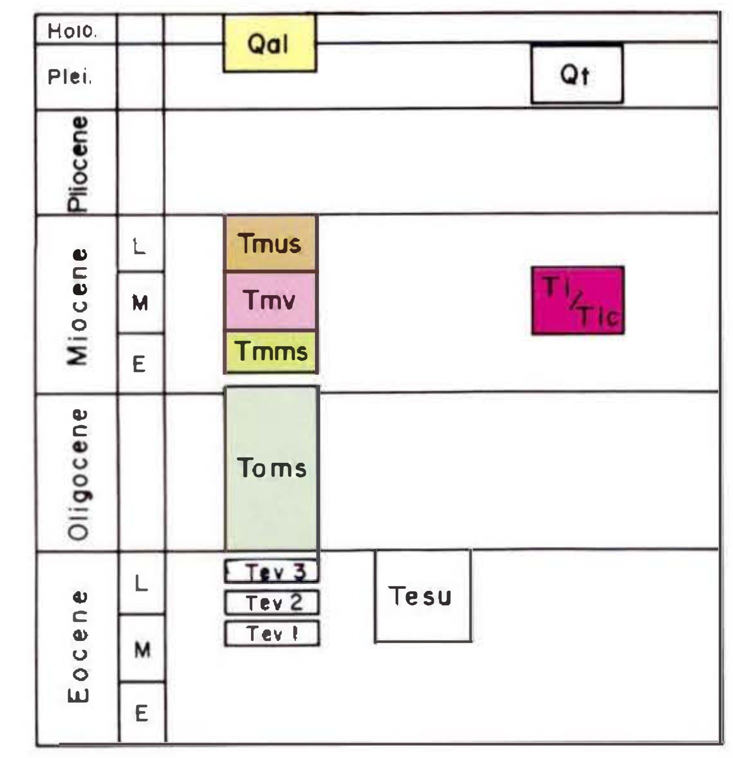
GEOLOGIC MAP

of the

CATHLAMET QUADRANGLE

OREGON

STRATIGRAPHIC TIME CHART



EXPLANATION

Unconsolidated Surficial Units

Qal — Quaternary Alluvium
Low-lying flood plains of the Columbia River consisting of sand and silt; also includes gravelly flood plains lining the lower reaches of Big Creek and Gnat Creek.

Qt — Quaternary Terrace Deposits
Dissected alluvium consisting primarily of poorly sorted silt, sand, and gravel.

Stratigraphic Units

Tmus — Upper Miocene Sandstone
Approximately 1,000 feet of massive, coarse- to fine-grained, arkosic sandstone passing upsection into sandy siltstone. Thick sandstone interbeds are present in the Miocene Volcanic Rock near Bradley State Park and on Nicolai Mountain. Subaqueous slump breccias are present locally.

Tmv — Miocene Volcanic Rock
Up to 1,500 feet of subaerial flow-on-flow basalt and subaqueous, palagonitic breccias of basaltic composition. Subaerial flow rock dominates in the south and east and breccias dominate in the lower Big Creek area. The basalts are petrochemically similar to the Yakima Basalt of Waters (1961).

Tmms — Middle Miocene Sandstone
Several hundred feet of massive, micaceous, arkosic sandstone and subordinate interbedded sandy siltstone immediately underlying the Miocene Volcanic Rock. Age equivalence with the Astoria Formation is inferred in the Big Creek drainage; age of small exposures in the Cathlamet quadrangle is less certain.

Toms — Oligocene to Miocene Sedimentary Rock
Greater than 5,000 feet of massive- to thin-bedded, medium- to dark-gray, tuffaceous siltstone and subordinate interbedded blocky sandstone. Probably includes Astoria-age siltstones in the middle reaches of Big Creek.

Ti — Intrusive Rock
Basaltic dikes and sill of middle Miocene age.

Geologic Symbols

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Contacts
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⊕ Horizontal Beds

⊥ Strike and dip of beds or flows

⚒ Rock quarries

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
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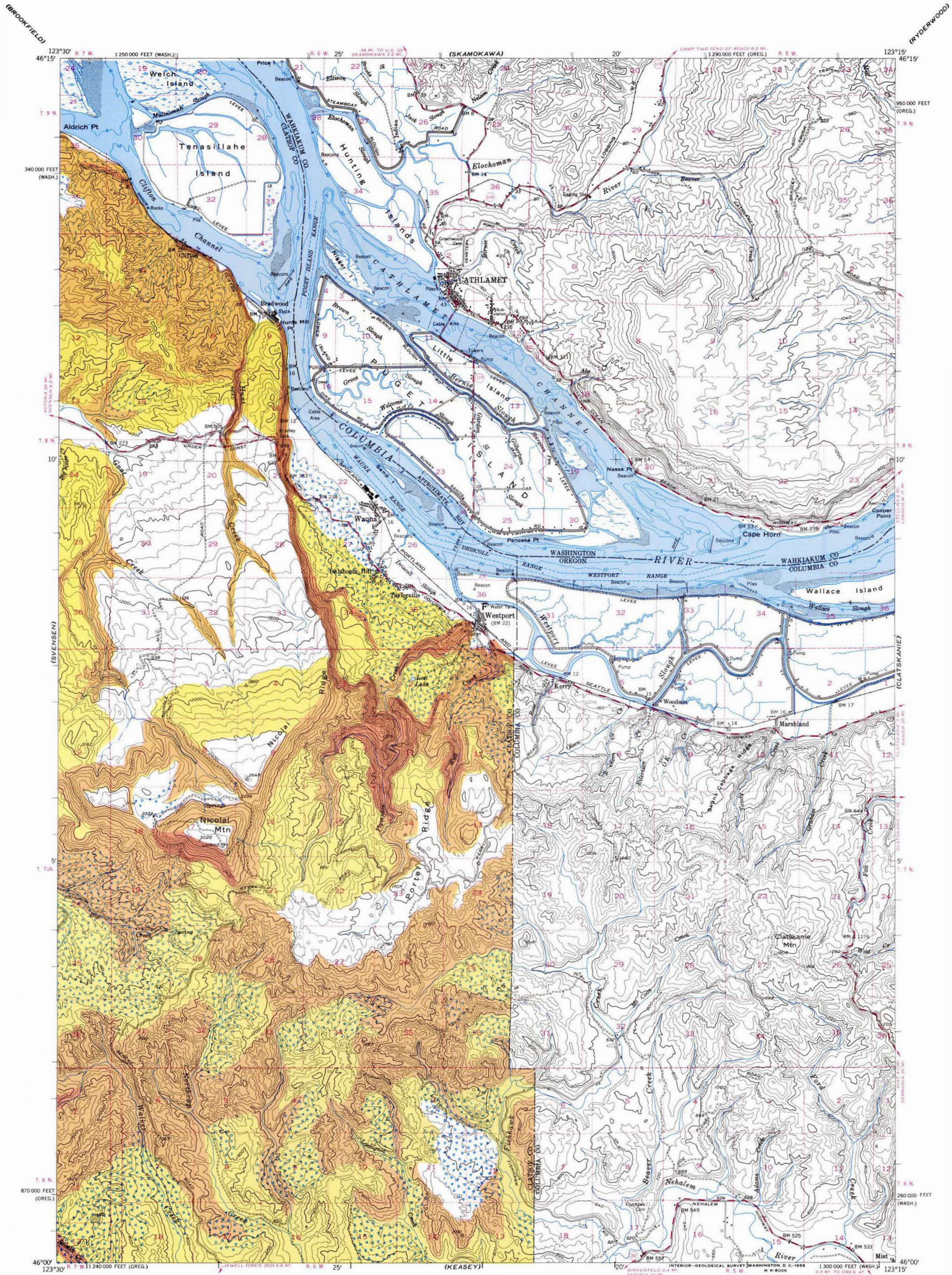
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

HAZARD MAP
of the
CATHLAMET QUADRANGLE
OREGON



Base map by U.S. Geological Survey
Control by USC&GS and USCE
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1951. Field check 1953
Hydrography compiled from USC&GS Chart 6152 (1951)
Polyconic projection. 1927 North American datum
10,000-foot grids based on Oregon coordinate system, north zone, and Washington coordinate system, south zone
Dashed land lines indicate approximate locations

SCALE 1:62500

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES IN FEET—COLUMBIA RIVER DATUM

APPROXIMATE MEAN DECLINATION, 1953

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty
Medium-duty
Light-duty
Unimproved dirt
U.S. Route
State Route

EXPLANATION

- 0 - 9% Slope
- 10 - 24% Slope
- 25 - 49% Slope
- >50% Slope

(Increasing danger of mass movement with increasing slope)

- Mass Movement Topography
- Mudflow
- Potential for Flash Flood
- Stream Bank Erosion

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

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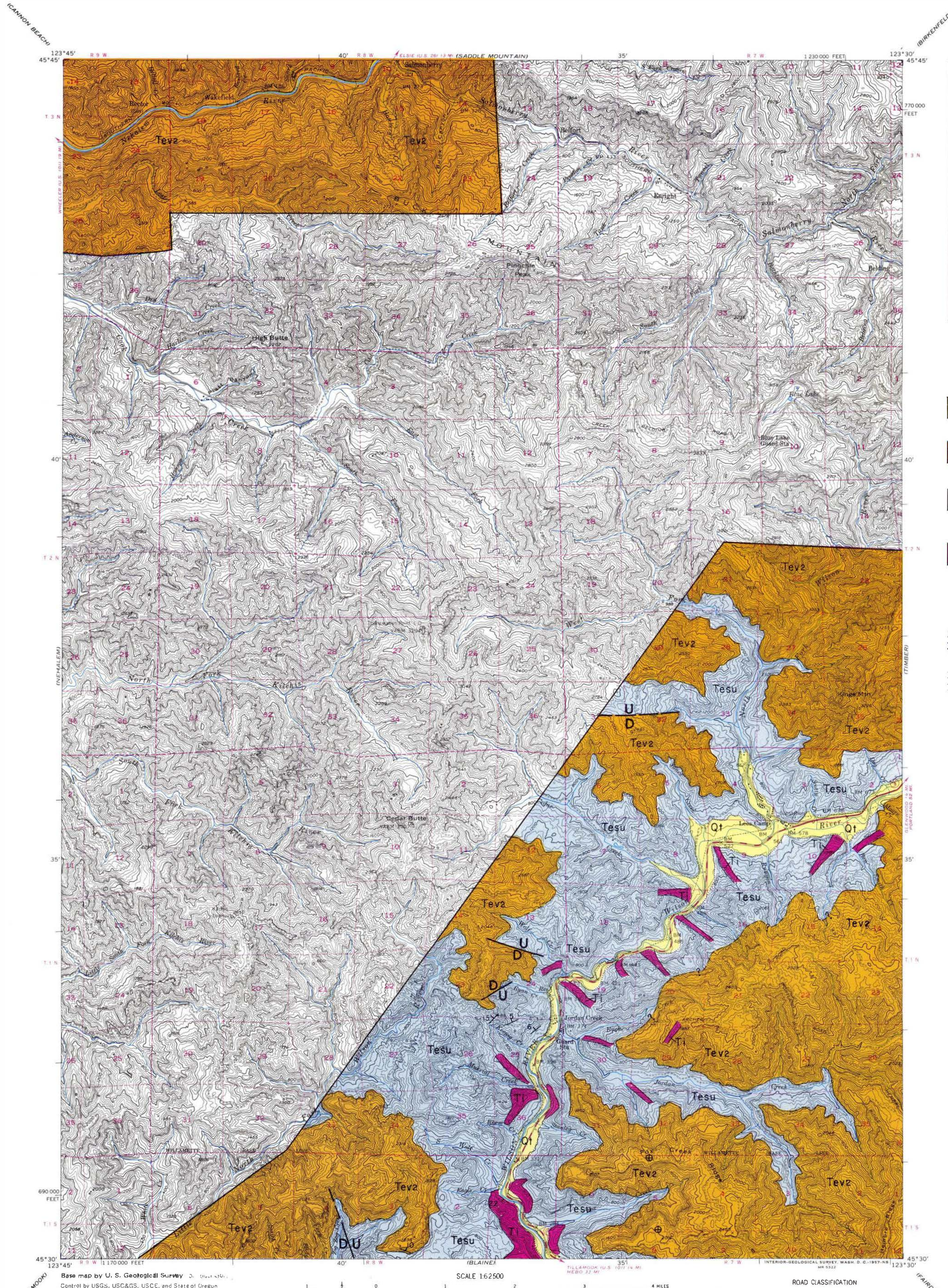
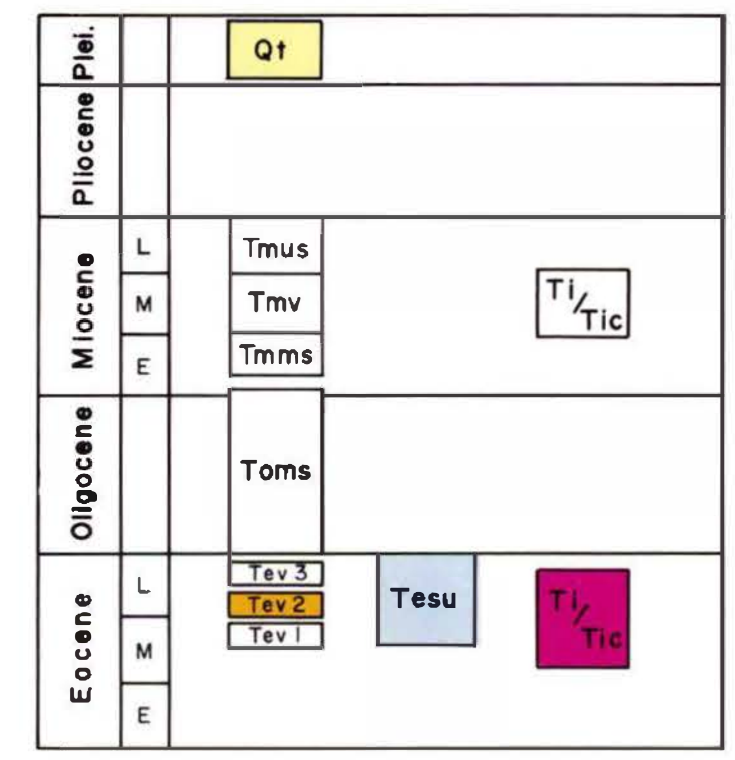
GEOLOGIC MAP
of the
ENRIGHT QUADRANGLE
OREGON





EXPLANATION

Unconsolidated Surficial Units

Qt — Quaternary Terrace Deposits
Dissected alluvium consisting primarily of poorly sorted silt, sand, and gravel.

Stratigraphic Units

Tev 2 — Eocene Volcanic Rock, Unit-2
At least 15,000 feet of basaltic breccia (Enright and Blaine quadrangles), submarine basaltic flow rock (Saddle Mountain quadrangle), and subaerial flow-on-flow basalt (Timber quadrangle) intercalated with subordinate amounts of tuffaceous, thin-bedded siltstone.

Tesu — Eocene Sedimentary Rock Undifferentiated
Several thousand feet of undifferentiated, thin-bedded to indistinctly bedded, tuffaceous, volcaniclastic siltstone, clay siltstone, and sandstone. The sedimentary rock occurs stratigraphically between the three Eocene volcanic units and grades laterally into them locally. Volcanic interbeds are present in places.

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Contacts
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⊕ Horizontal Beds

Strike and dip of beds or flows

⚒ Rock quarries

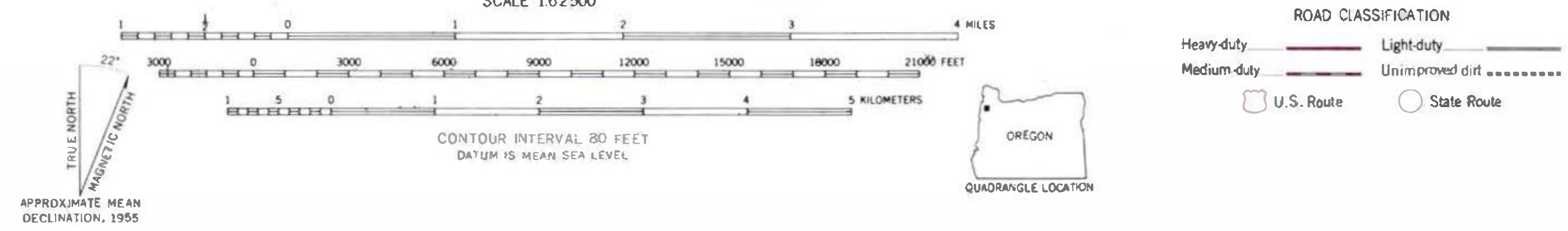
Base map by U. S. Geological Survey

Control by USGS, USC&GS, USCE, and State of Oregon

Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Field check 1955

Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone

Dashed land lines indicate approximate locations



Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

HAZARD MAP
of the
ENRIGHT QUADRANGLE
OREGON

EXPLANATION

0 - 9% Slope

10 - 24% Slope

25 - 49% Slope

>50% Slope

(Increasing danger of mass movement with increasing slope)

Mass Movement Topography

Mudflow

Potential for Flash Flood

Stream Bank Erosion

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
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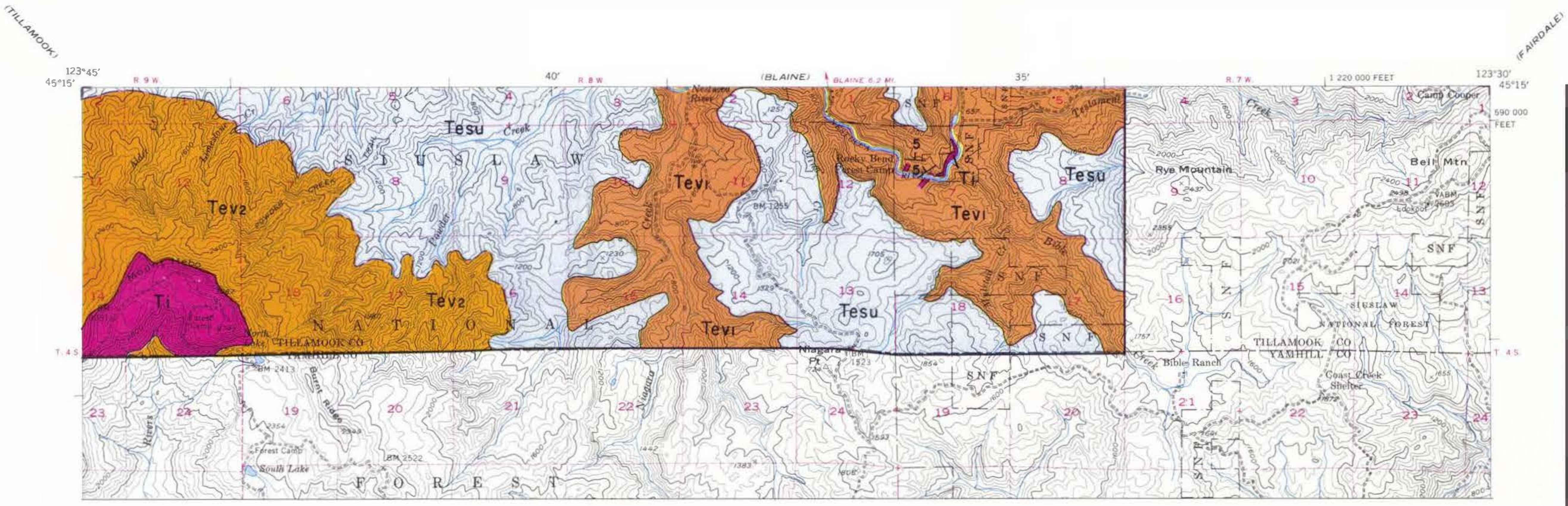
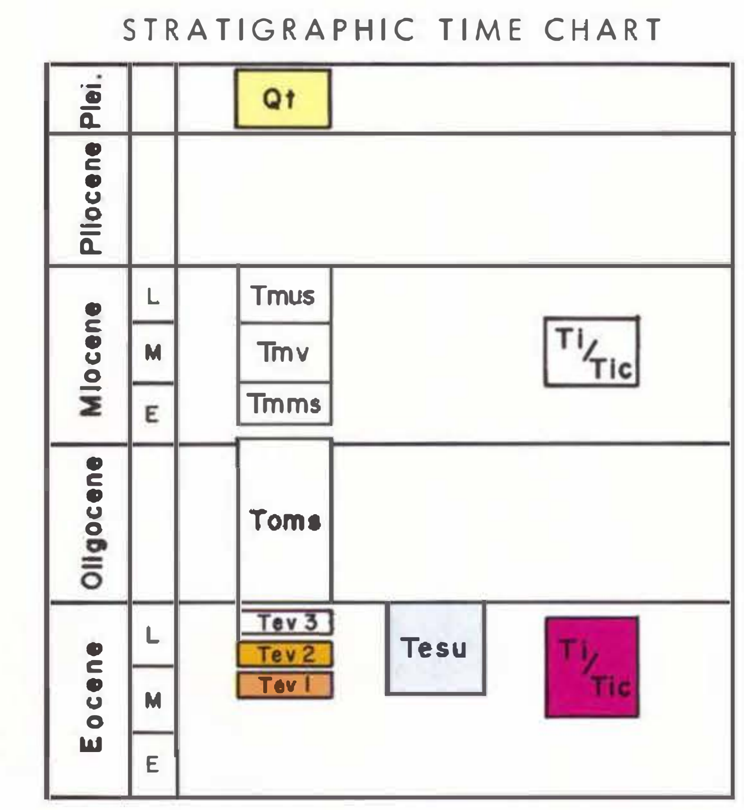
GEOLOGIC MAPS
of portions of the

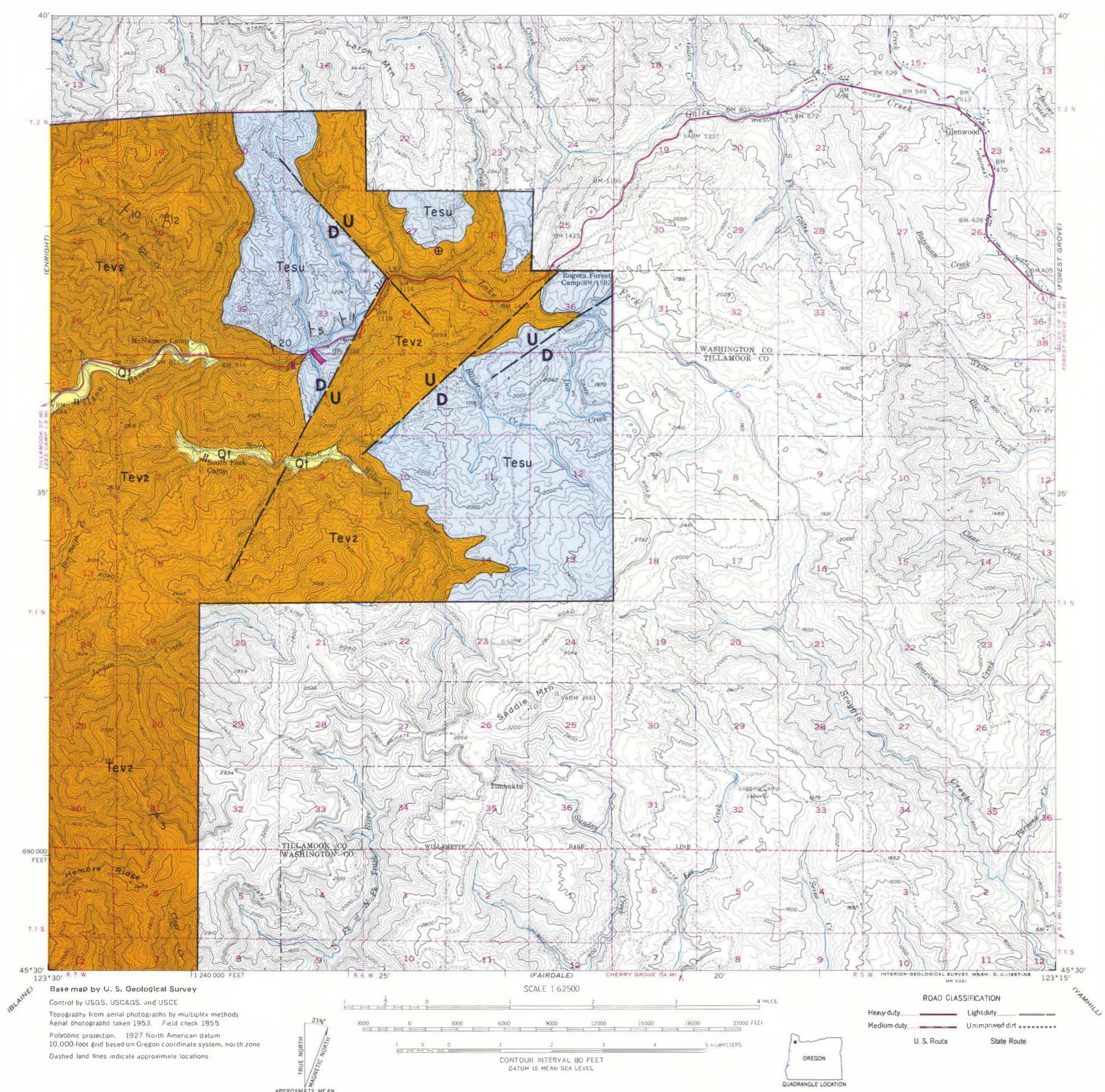
GRAND RONDE & TIMBER QUADRANGLES
OREGON



GRAND RONDE



TIMBER



EXPLANATION

Unconsolidated Surficial Units

Qt — Quaternary Terrace Deposits

Dissected alluvium consisting primarily of poorly sorted silt, sand, and gravel.

Stratigraphic Units

Tev 2 — Eocene Volcanic Rock, Unit-2

At least 15,000 feet of basaltic breccia (Enright and Blaine quadrangles), submarine basaltic flow rock (Saddle Mountain quadrangle), and subaerial flow-on-flow basalt (Timber quadrangle) intercalated with subordinate amounts of tuffaceous, thin-bedded siltstone.

Tev 1 — Eocene Volcanic Rock, Unit-1

Approximately 1,000 feet of pillow basalt and zeolite-cemented basaltic breccia intercalated with bedded siltstone in the valley bottoms of the Nestucca River drainage.

Tesu — Eocene Sedimentary Rock Undifferentiated

Several thousand feet of undifferentiated, thin-bedded to indistinctly bedded, tuffaceous, volcaniclastic siltstone, clay siltstone, and sandstone. The sedimentary rock occurs stratigraphically between the three Eocene volcanic units and grades laterally into them locally. Volcanic interbeds are present in places.

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Basaltic intrusive rock of late Eocene and middle Miocene age including dikes and sills (Ti) and complex associations of intrusive rock and sedimentary rock (Tic). The Miocene intrusions are restricted to post-Eocene terrain and are characterized by a dense, uniformly grained texture. Eocene intrusions commonly contain indistinct phenocrysts of pyroxene.

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⊕ Horizontal Beds

⊥ Strike and dip of beds or flows

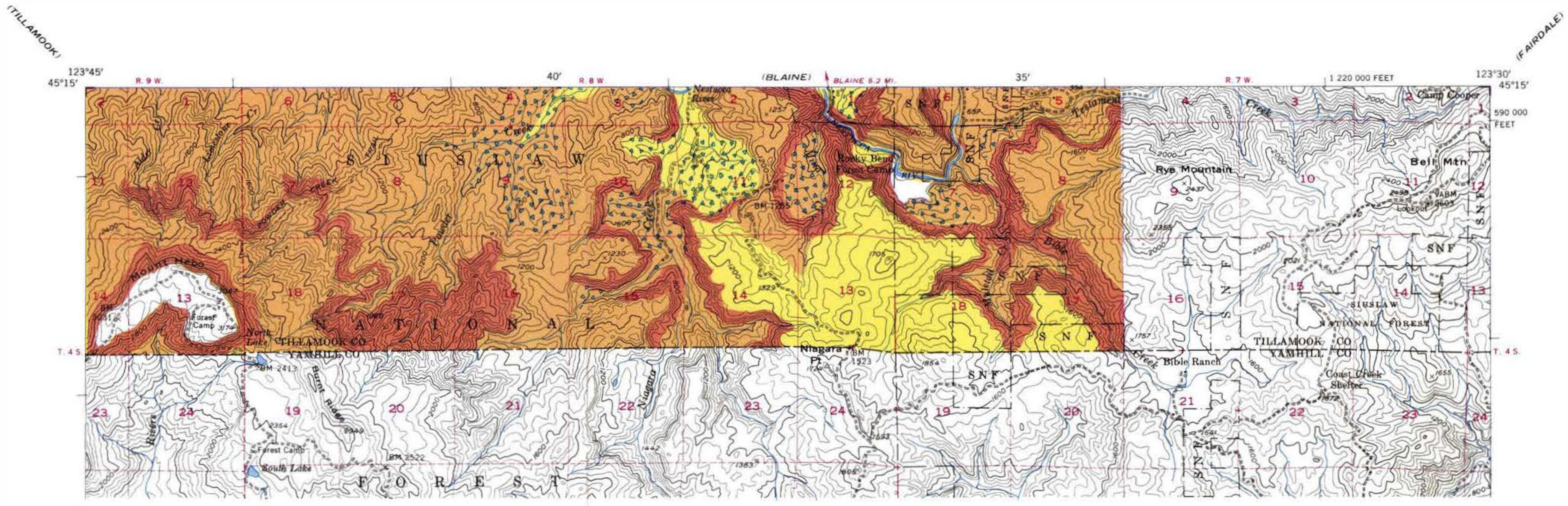
⚒ Rock quarries

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

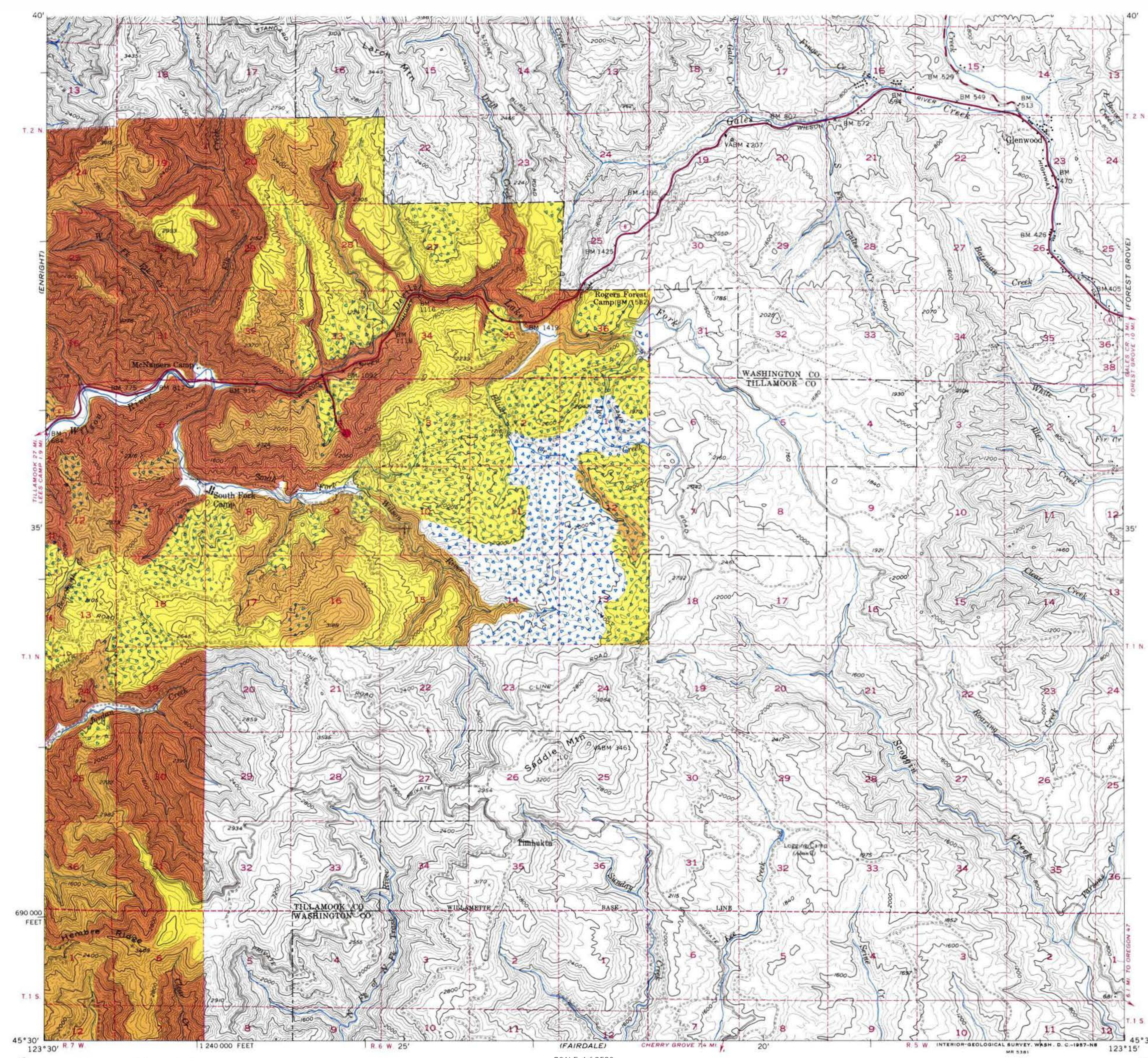
Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

HAZARD MAPS
of portions of the
GRAND RONDE & TIMBER QUADRANGLES
OREGON



GRAND RONDE

TIMBER



EXPLANATION

- 0 - 9% Slope
- 10 - 24% Slope
- 25 - 49% Slope
- > 50% Slope

(Increasing danger of mass movement with increasing slope)

- Mass Movement Topography
- Mudflow
- Potential for Flash Flood
- Stream Bank Erosion

Base map by U. S. Geological Survey
Control by USGS, USC&GS, and USCE
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Field check 1955
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
Dashed land lines indicate approximate locations

APPROXIMATE MEAN DECLINATION, 1955

SCALE 1:62500

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

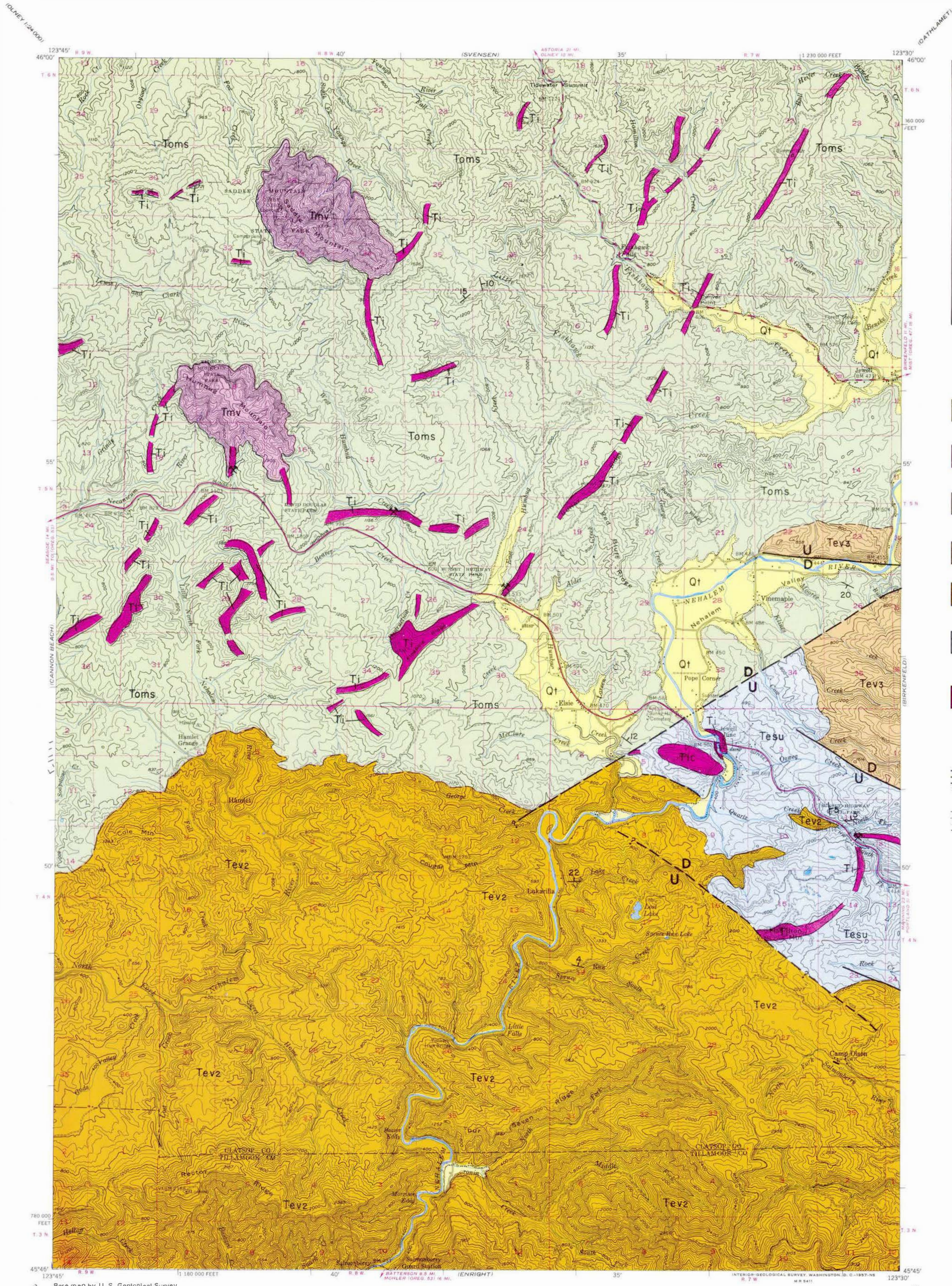
ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U.S. Route — State Route

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

GEOLOGIC MAP
of the
SADDLE MOUNTAIN QUADRANGLE
OREGON



Base map by U. S. Geological Survey
Control by USGS, USC&GS, USCE, and State of Oregon
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Field check 1955
Polyconic projection. 1927 North American datum
0,000-foot grid based on Oregon coordinate system, north zone
ashed land lines indicate approximate locations

SCALE 1:62500

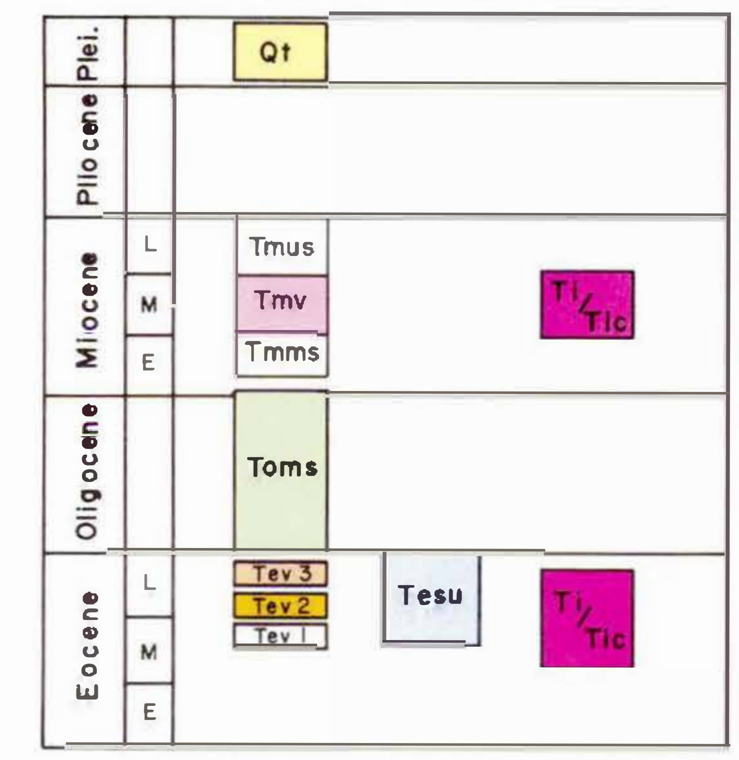
CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1955

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route — State Route

STRATIGRAPHIC TIME CHART



EXPLANATION

Unconsolidated Surficial Units

Qt — Quaternary Terrace Deposits
Dissected alluvium consisting primarily of poorly sorted silt, sand, and gravel.

Stratigraphic Units

Tmv — Miocene Volcanic Rock
Localized accumulations of massive basalt breccia (Humbug Mountain and Saddle Mountain), and basaltic palogonite breccias. The basalts are petrochemically indistinguishable from the Yakima Basalt (Snavely, MacLeod, and Rau, 1969).

Toms — Oligocene to Miocene Sedimentary Rock
Greater than 5,000 feet of massive- to thin-bedded, medium- to dark-gray, tuffaceous siltstone with subordinate amounts of sandstone locally. Includes Astoria age strata at the base of Saddle Mountain and Humbug Mountain.

Tev 3 — Eocene Volcanic Rock, Unit-3
Several thousand feet of relatively flat-lying basaltic flow rock and pillow basalts of marine and subaerial origin intercalated with subordinate amounts of shallow-water volcaniclastic sedimentary rock.

Tev 2 — Eocene Volcanic Rock, Unit-2
At least 15,000 feet of basaltic breccia (Enright and Blaine quadrangles), submarine basaltic flow rock (Saddle Mountain quadrangle), and subaerial flow-on-flow basalt (Timber quadrangle) intercalated with subordinate amounts of tuffaceous, thin-bedded siltstone.

Tesu — Eocene Sedimentary Rock Undifferentiated
Several thousand feet of undifferentiated, thin-bedded to indistinctly bedded, tuffaceous, volcaniclastic siltstone, clay siltstone, and sandstone. The sedimentary rock occurs stratigraphically between the three Eocene volcanic units and grades laterally into them locally. Volcanic interbeds are present in places.

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Faults
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Contacts
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⊕ Horizontal Beds

Strike and dip of beds or flows

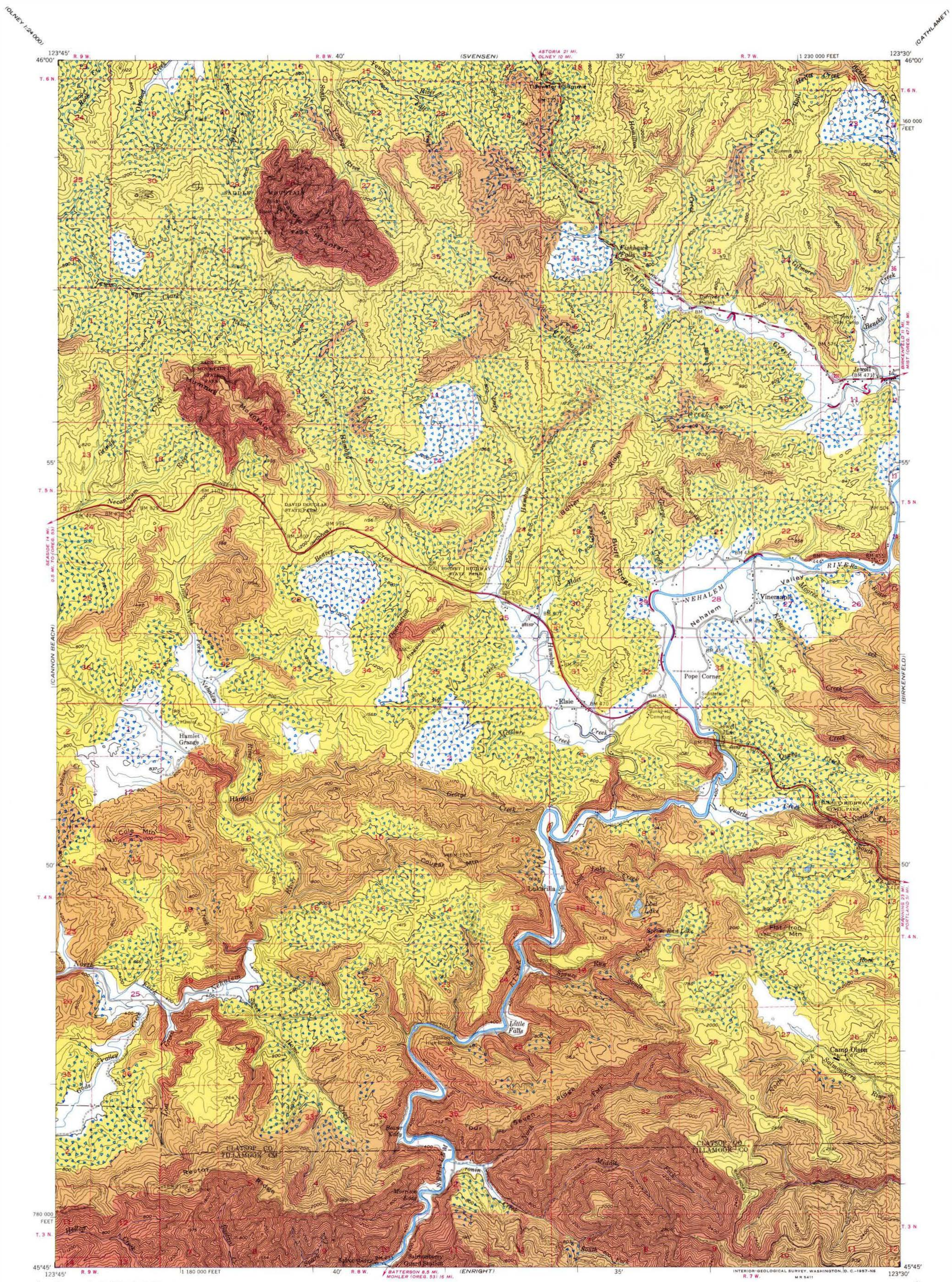
Rock quarries

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

HAZARD MAP
of the
SADDLE MOUNTAIN QUADRANGLE
OREGON



Base map by U.S. Geological Survey
Control by USGS, USC&GS, USCE, and State of Oregon
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Field check 1955
Polyconic projection. 1927 North American datum
0,000-foot grid based on Oregon coordinate system, north zone
ashed land lines indicate approximate locations

SCALE 1:62 500

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

TRUE NORTH
MAGNETIC NORTH
22°
APPROXIMATE MEAN DECLINATION, 1955

OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty
Light-duty
Medium-duty
Unimproved dirt
U.S. Route
State Route

EXPLANATION

0 - 9% Slope

10 - 24% Slope

25 - 49% Slope

> 50% Slope

(Increasing danger of mass movement with increasing slope)

Mass Movement Topography

Mudflow

Potential for Flash Flood

Stream Bank Erosion

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
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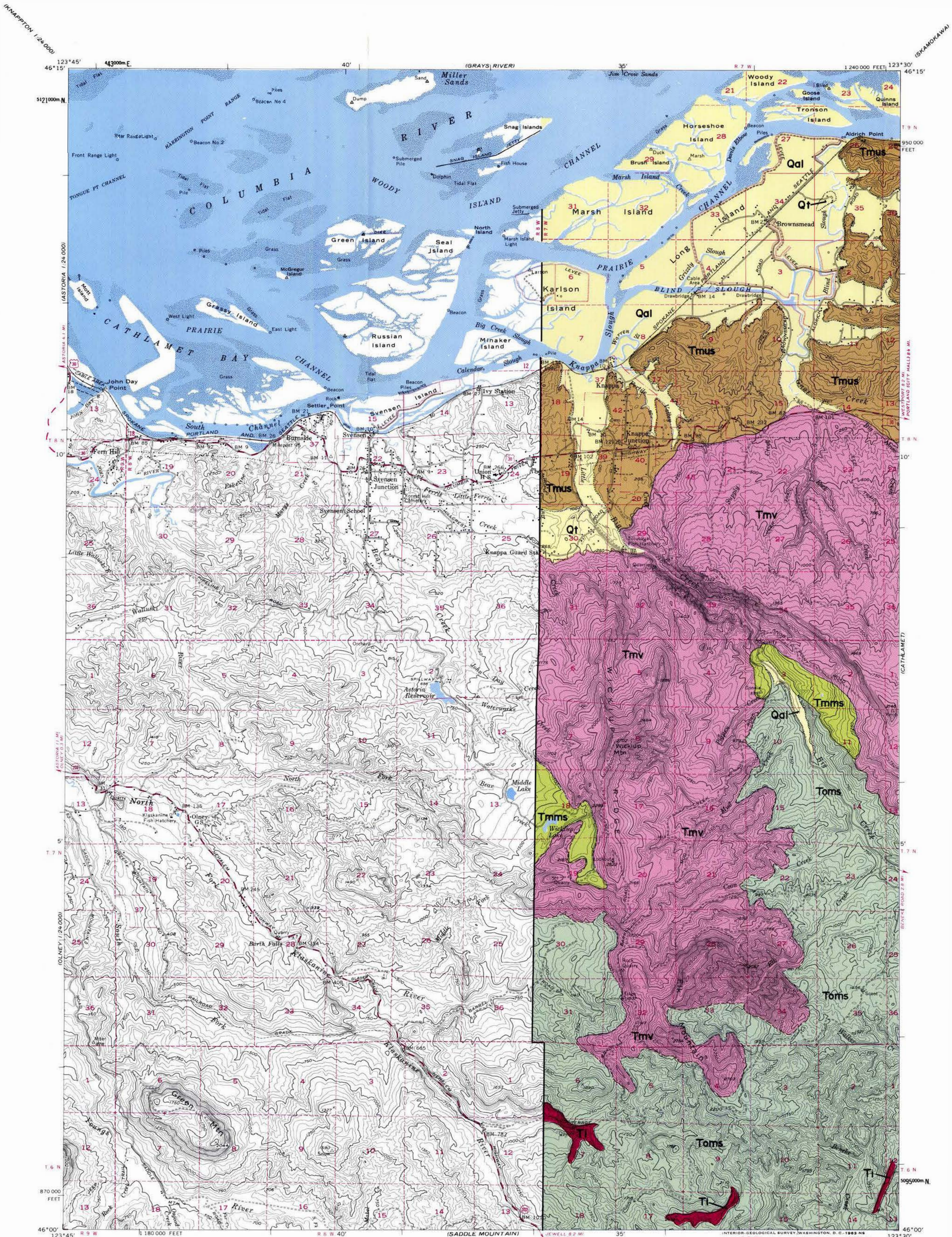
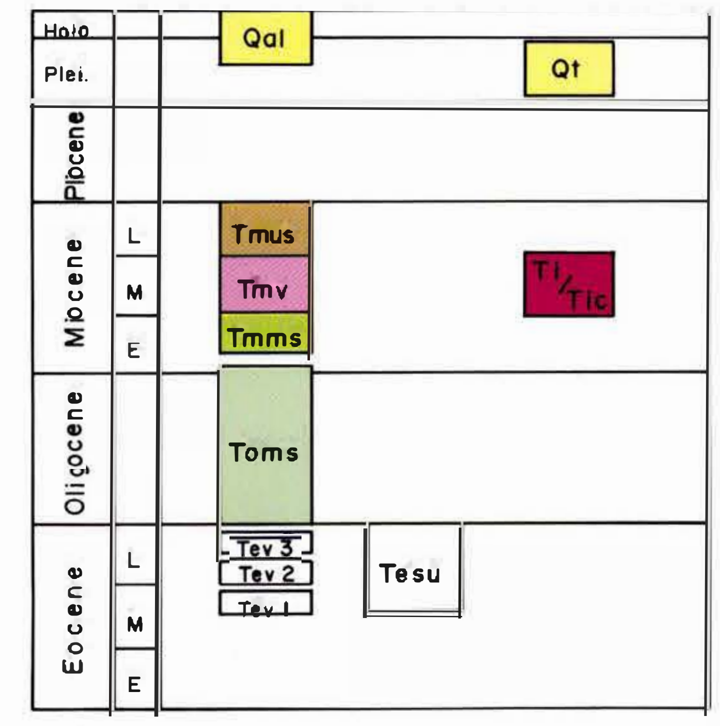
R. E. CORCORAN, STATE GEOLOGIST

GEOLOGIC MAP
of the
SVENSEN QUADRANGLE
OREGON



STRATIGRAPHIC TIME CHART



EXPLANATION

Unconsolidated Surficial Units

Qal — Quaternary Alluvium
Low-lying flood plains of the Columbia River consisting of sand and silt; also includes gravelly flood plains lining the lower reaches of Big Creek and Gnat Creek.

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Several hundred feet of massive, micaceous, arkosic sandstone and subordinate interbedded sandy siltstone immediately underlying the Miocene Volcanic Rock. Age equivalence with the Astoria Formation is inferred in the Big Creek drainage; age of small exposures in the Cathlamet quadrangle is less certain.

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Basaltic dikes and sill of middle Miocene age.

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Base map by U.S. Geological Survey
Edited and published by the Geological Survey
Control by USGS, USC&GS, USCE, and State of Oregon
Topography by multiplex methods from aerial photographs taken 1943 and 1953. Cultural revision and field check 1955
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue
Hydrography compiled from USC&GS charts 6151 (1954) and 6152 (1955)
Dashed land lines indicate approximate locations

APPROXIMATE MEAN DECLINATION, 1955

SCALE 1:62500

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES IN FEET–DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 6 FEET

QUADRANGLE LOCATION

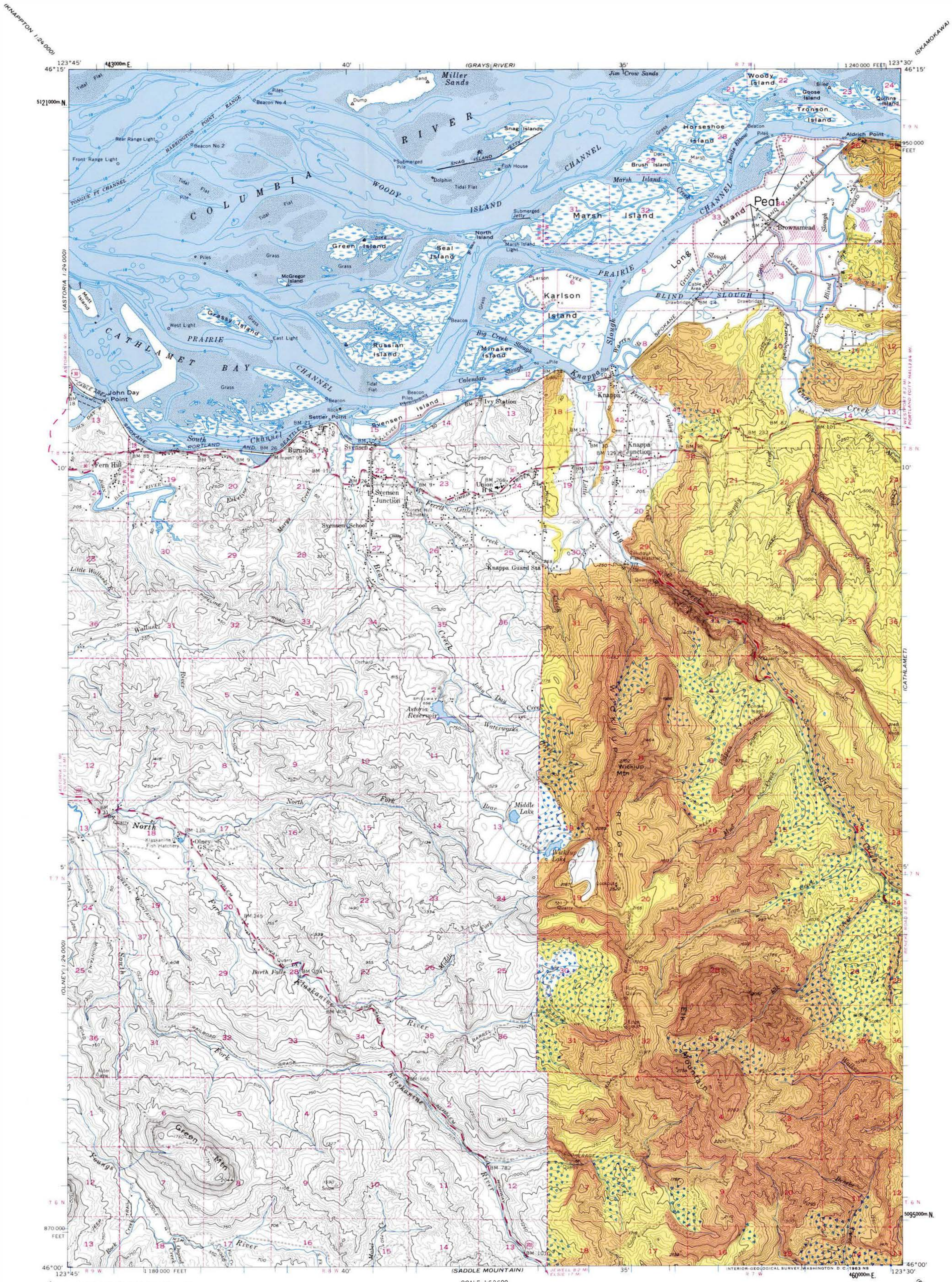
ROAD CLASSIFICATION
Medium-duty — Light-duty
Unimproved dirt
U. S. Route — State Route

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

HAZARD MAP
of the
SVENSEN QUADRANGLE
OREGON



Base map by U.S. Geological Survey
Edited and published by the Geological Survey

Control by USGS, USC&GS, USCE, and State of Oregon

Topography by multiplex methods from aerial photographs taken 1943 and 1953. Cultural revision and field check 1955

Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

Hydrography compiled from USC&GS charts 6151 (1954) and 6152 (1955)

Dashed land lines indicate approximate locations

EXPLANATION

0 - 9% Slope

10 - 24% Slope

25 - 49% Slope

> 50% Slope

(Increasing danger of mass movement with increasing slope)

Mass Movement Topography

Mudflow

Potential for Flash Flood

Stream Bank Erosion

Geology by John D. Beaulieu, 1972

Cartography by S. R. Renoud and M. E. Lawson

Map prepared by
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